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2015 Assessment of Northern Shrimp *(Pandalus borealis)* and Striped Shrimp *(Pandalus montagui)* in the Eastern and Western Assessment Zones (SFAs Nunavut, Nunavik and Davis Strait)

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Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

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ABSTRACT

The status of the Northern Shrimp (*Pandalus borealis*) and Striped Shrimp (*P. montagui*) resources in the Eastern Assessment Zone (EAZ) was assessed based on the results of fishery-independent surveys conducted by the Northern Shrimp Research Foundation (NSRF)-DFO for the years 2006–2014 and commercial catch statistics. Results from individual survey areas within the EAZ are provided. Northern Shrimp were assessed to be well within the Healthy Zone of the Precautionary Approach Framework even though biomass showed a decline over the past three years, albeit year to year differences are statistically insignificant. The potential exploitation rate for 2014/15, based on the TAC of 8,250 t, is about 16.4%. Striped Shrimp biomass has fluctuated widely over the past four surveys making interpretation of the time series problematic. These fluctuations moved Striped Shrimp from low in the Cautious Zone in 2013/14 to well into the Healthy Zone in 2014/15. Therefore, caution is advised when setting the TAC for the 2015/16 fishing season.

Prior to 2014, the status of the Northern Shrimp and Striped Shrimp resources in the Western Assessment Zone (WAZ) was based on surveys conducted by DFO. The area was surveyed with a different ship, trawl gear and at a different time of year than the EAZ. Since no trawl standardization had been conducted, the results from the two zones could not be combined and therefore the resource could not be assessed in its entirety across both zones. This was resolved in 2014 by having the NSRF-DFO survey the WAZ in conjunction with the EAZ survey. This action restarts the times series. The exploitation rate indices are 7% and 8% for Northern Shrimp and Striped Shrimp, respectively, in the WAZ in 2014. These rates are well below that seen in other Canadian Shrimp Fishing Areas and so appear to be conservative. Since the 2014 results are not comparable to previous surveys, it is advised that the TAC remain at status quo until there is an adequate time series with which to develop reference points for the WAZ.

Évaluation des stocks de crevette nordique (*Pandalus borealis*) et de crevette ésope (*Pandalus montagui*) dans les zones d'évaluation Est et Ouest (zones de pêche à la crevette du Nunavut, du Nunavik et du détroit de Davis) en 2015

RÉSUMÉ

L'état du stock des ressources de crevette nordique (*Pandalus borealis*) et de crevette ésope (*P. montagui*) dans la zone d'évaluation Est a été évalué en fonction des statistiques des prises commerciales et des résultats de relevés indépendants de la pêche menés par la Northern Shrimp Research Foundation (NSRF) et Pêches et Océans Canada (MPO) pour les années 2006 à 2014. Les résultats de chaque zone de relevé faisant partie de la zone d'évaluation Est sont également fournis. Selon l'évaluation, la crevette nordique se trouve bien à l'intérieur de la zone saine du Cadre de l'approche de précaution, même si sa biomasse a présenté un déclin au cours des trois dernières années; les différences d'une année à l'autre ne sont pas significatives d'un point de vue statistique. Le taux d'exploitation potentiel pour l'exercice 2014-2015, fondé sur le total autorisé des captures (TAC) de 8 250 t, est d'environ 16,4 %. La biomasse de la crevette ésope a fluctué grandement au cours des quatre derniers relevés, ce qui complique l'interprétation de la série chronologique. Ces fluctuations ont fait passer la crevette ésope de la partie inférieure de la zone de prudence en 2013-2014 à la zone saine, bien au-dessus du point de référence supérieur en 2014-2015. Par conséquent, il convient d'être prudent au moment d'établir le TAC pour la saison de pêche de 2015-2016.

Avant 2014, l'état des ressources de crevette nordique et de crevette ésope dans la zone d'évaluation Ouest était basé sur les relevés effectués par le MPO. La zone a fait l'objet de relevés effectués avec un navire différent, un autre engin de chalutage, et à une autre période de l'année que la zone d'évaluation Est. Comme les chaluts n'ont pas été normalisés entre les relevés, il n'a pas été possible de combiner les résultats des deux zones et, par conséquent, la ressource n'a pas pu être évaluée dans son intégralité dans les deux zones. Ce problème a été résolu en 2014 en organisant le relevé effectué par la NSRF et le MPO dans la zone d'évaluation Ouest conjointement avec celui de la zone d'évaluation Est. Cette mesure marque le début d'une nouvelle série chronologique. Les indices du taux d'exploitation sont de 7 % et de 8 % respectivement, pour la crevette nordique et la crevette ésope dans la zone d'évaluation Ouest en 2014. Ces taux sont bien inférieurs à ceux observés dans d'autres zones de la pêche de la crevette au Canada et peuvent ainsi sembler conservateurs. Puisque les résultats de 2014 ne sont pas comparables à ceux des relevés précédents, il est recommandé de maintenir le statu quo du TAC jusqu'à ce que l'on dispose d'une série chronologique adéquate pour élaborer des points de référence pour la zone d'évaluation Ouest.

INTRODUCTION

Central and Arctic Region Resource Management requested an assessment of the shrimp resources in Shrimp Fishing Areas (SFA) Nunavut, Nunavik and Davis Strait (Figure 1). The shrimp resources were assessed within the Eastern Assessment Zone (EAZ) and Western Assessment Zone (WAZ) (Figure 2) based on four survey areas each with independently allocated stations (Figure 3).

Prior to 2014, two surveys were conducted to produce the data required to assess the shrimp resources within Fisheries and Oceans Canada's (DFO) Central and Arctic region. In 2003, the 17 license holders of the offshore shrimp industry formed the Northern Shrimp Research Foundation (NSRF). In 2005, the NSRF in partnership with DFO (NSRF-DFO) began an annual survey based on the boundaries of North Atlantic Fisheries Organization (NAFO) Divisions 0B and 2G. The area of 0B roughly equated to Shrimp Fishing Area (SFA) 2 and 2G to SFA 4. In order to ensure the main historical fishing areas were surveyed, in 2006, the 0B survey was expanded and split into two survey areas called SFA 2 Exploratory (SFA2EX) and Resolution Island Survey Area (RISA) Survey Areas (Figure 3). For resource assessment purposes these two survey areas were combined at the 2011 Zonal Assessment Process (ZAP) and designated as the EAZ (Figure 2). In 2007, DFO expanded its multi-species assessment survey series to include SFA 3 west of 66°W and repeated biennial surveys of this area in 2009, 2011 and 2013 (Figure 1). The SFA 3 survey area (Figure 2) was designated as the WAZ at the 2011 ZAP (DFO 2011). The shrimp in the EAZ and WAZ do not recognise man-made boundaries and very likely shift across the zones in this high energetic region. Because the two surveys were conducted with a different ship, gear and months apart, the population of the two zones cannot be examined as a whole because no trawl standardization had been conducted. To resolve this, the NSRF has been engaged to sample the WAZ in conjunction with the EAZ survey. The first NSRF-DFO survey of the WAZ was in 2014 which is now planned to be an annual survey. While this resolves the issues noted above, the action resets the time-series.

This document presents the results of research surveys conducted in the EAZ and WAZ through the 2014 survey. Fisheries data and fisheries-independent research survey results are the basis of the assessment of Northern and Striped Shrimps in the EAZ and WAZ. The assessment follows the framework developed for SFA4-6 (DFO 2007a) where possible. The EAZ and WAZ were last assessed in 2013 (DFO 2013) and 2010 (DFO 2010), respectively, and the resource status indicators updated in 2012 (DFO 2012) and 2014 (DFO 2014).

MATERIALS AND METHODS

SURVEY DESIGN AND PRACTICES

Four survey areas are located within the bounds of the EAZ and WAZ (Figure 2). From 2006-2013, two separate research surveys were conducted to sample the survey areas. Surveys of the SFA2EX and the RISA survey areas (Figure 1) were conducted by NSRF-DFO. The WAZ (Figure 1) was surveyed by DFO west of the RISA-W survey area. Both surveys are equivalent in survey design, catch processing and survey analysis, but were sampled with different vessels, trawl gear and time of year as detailed below. Both trawl surveys provide the fishery-independent data required for the assessment of Pandalid shrimp stock status in the EAZ and WAZ (SFA 2 and 3). In 2014, the Central and Arctic Region reorganized surveys within the region. To remove the issues around conducting two separate surveys, the NSRF-DFO was engaged to conduct the survey of WAZ while it samples the EAZ. While this move resolves

issues of comparability it restarts the time series since no trawl work has been undertaken to standardize the two surveys.

SFA2EX and RISA Survey Areas

The first NSRF-DFO survey in 2005 was designed within the borders of NAFO Div. 0B. In 2006, to better encompass the historical shrimp-fishery footprint and align better with management units, the 0B survey area was expanded westward to 66°W and south 60°30'N, then split into two survey areas designated as SFA2EX and RISA. Both survey areas cover depths between 100 and 750 m divided into contours of 100-200, 200-300, 300-400, 400-500, and 500-750 m. Depth contours are further subdivided into sampling strata.

In 2006, the total area of SFA2EX was 103,331 km^2. In 2009, a small 200-300 m stratum was removed from the survey area because the bottom was found to be untrawlable. At the same time, the shrimp industry implemented a voluntary closed area which overlapped the southern part of the SFA2EX and also removed from the survey design. Consequently the SFA2EX area has been reduced to a total area of 99,117 km^2. RISA had a total area of 28,321 km^2 in 2006. In 2007, experience with untrawlable bottom combined with safety concerns for the ship prompted the removal of the 100-200 m strata from RISA. Grid cells determined to be untrawlable were also removed from the survey design. These combined removals in RISA have reduced its total area to 21,900 km^2 from 2010 onward.

In 2005, Doubleday's (1981) method was used to allocate sampling sites based on the NAFO stratifications. In 2006, the redesign of the survey areas, which extended outside the NAFO boundary, required a revision to the stratification scheme. The new area added to the survey was stratified to and matched with the existing contours. A 3 by 3 km grid was superimposed over an equal-area projection of the stratified survey area. To continue using the Doubleday method, large blocks were formed from nine grid points in a square pattern wherever possible. The actual number of grid points varied depending on the curvature of the stratum border. In 2005 and 2006 in SFA2EX and RISA, the samples are allocated in proportion to stratum area with a two set minimum regardless of stratum size. Starting in 2007 in SFA2EX, 87 samples are proportionally allocated by stratum area and an additional 34 sets allocated optimally (Cochran 1977) based on the variance observed within strata in the two previous surveys in an effort to control overall confidence intervals of the biomass estimate. Sampling sites were located by first randomly selecting the appropriate number of large blocks as allocated to a stratum, then randomly selecting a single grid point from within each of the selected large blocks. RISA continued to be proportionally allocated.

SFA2EX and RISA surveys are conducted annually in August using the fishing vessel *Cape Ballard* with a Campelen 1800 shrimp trawl (Walsh et al. 2009). The *Cape Ballard* is a 45.9 m (992 GRT) stern trawler owned by Ocean Choice International. The trawl was spread with Morgere® Polyvalent doors 4.3 m2 in area weighing 1400 kg. In 2012, the *Cape Ballard* was replaced with the *Aqviq*. Analysis concluded that given the similarity in specification, conversion factors would not be required to continue with a comparable time series (S. Walsh, DFO Emeritus, pers. comm.). In 2014, when the *Aqviq* became unserviceable its sister ship, the Kinguk, was used for the survey.

The standard Campelen trawl has 14 inch rubber disk 'rockhopper' ground gear with a single cod end fitted with a 12.7 mm mesh liner. Use of the Campelen trawl in the north resulted in many tear ups of the gear, especially in RISA, so a modified Campelen trawl was developed. Changes to the trawl increased the footgear size to 21 inches, floated the fishing line to reduce the weight of the trawl, increased the length of the toggles and added a polypropylene float rope to the lower rib line (Siferd and Legge 2014). Dimensions and mesh sizes in the trawl body were not changed. In 2008, the modified Campelen trawl was used in RISA with no tear ups

recorded. The modified Campelen was used in both the SFA2EX and RISA survey areas in 2009 and will continue to be used in future surveys of the two areas.

A 1 m by 1 m juvenile shrimp net made of 12.7 mm mesh (Nilssen et al. 1986; Aschan and Sunnan 1997) was attached to the third belly of the trawl forward of the cod end attachment. Samples collected in the juvenile shrimp net were weighed, in some cases subsampled and the final sample frozen on-board the ship and returned to the lab ashore for processing.

Trawl monitoring was problematic on the *Cape Ballard*. Various trawl monitoring systems have been used to observe trawl geometry; Netmind® (2005-2006) was replaced by Scanmar® (2007-2009). The current configuration (2010 onward) has used a Marport® MBAR with Marport and Scanmar spread sensors to measure door spread and wing spread. In 2010, a Furuno® trawl eye mounted on the headline was also added to improve the visualization of trawl touchdown and therefore start/end of tows. Prior to 2010, bottom time was measured from depth-time traces recorded with a Seabird® CTD mounted on the headline. In 2010, Marport recordings of the Furuno trawl eye were used to determine the start and end of the tow and thereby bottom time. Sampling was conducted on a 24 hour basis.

The swept area of each tow was determined through the multiplication of speed, bottom time and wing spread. Prior to 2010, speed was determined from the average of five GPS speeds recorded on deck sheets distributed evenly over the 15 minute duration of the tow. In 2010, the average of all speeds from GPS GPRMC strings recorded by the Marport system over the duration of the tow was used. Wing spread was determined either through direct measurement or by conversion from door spread through the formula derived from a comparison of door spread to wing spread over tows where both measures were present. All available wing spread measurements (direct or derived) were averaged over the duration of the tow. Bottom time was determined from depth-time recordings Seabird CTD (2005-2009) or Marport recordings of the Furuno trawl eye (2010 onward).

Water temperature and salinity was recorded with a trawl mounted Seabird 19plus CTD. Mean bottom temperature and salinity was considered the average of all measurements taken between the start and end of the tow while the trawl was on bottom.

WAZ Survey Area

The WAZ survey area has a total area of 58,279 km^2 covering the depths of 100 to 1,000 m divided into contours of 100-200, 200-300, 300-400, 400-500, 500-750 and 750-1,000 m for DFO surveys conducted between 2007 and 2013. The bathymetry of WAZ is such that natural strata were produced and no further subdivision of the contours was made. The WAZ is surveyed biennially. Four surveys of the area have been completed to date; 14-25 October 2007, 9-16 October 2009, 29 September–8 October 2011 and 29 September-9 October 2013.

In WAZ, sampling stations within a stratum were allocated in proportion to stratum area but with the requirement of a two set minimum regardless of stratum size. All possible sampling sites within a survey area based on a 3 by 3 km grid overlaying an equal-area projection of the stratified area were assigned to individual strata. A program developed by the Greenland Institute of Natural Resources (GINR) for buffered random sampling (Kingsley et al. 2004) was used to select sampling stations within each stratum of the study area.

The WAZ survey areas are sampled using the GINR research vessel *Paamiut* towing a Cosmos® 2000 shrimp trawl. The *Paamiut* is a 58.9 m (722 GRT) stern. The Cosmos trawl has 21 inch rubber-disk and bobbin 'rockhopper' ground gear. The trawl has twin cod-ends with an inner liner of 20 mm stretched mesh. Injector International® 7.5 m^2 doors weighing 2,800 kg spread the trawl. Standard sampling procedures are to maintain a speed of 2.6 knots for 15

minutes for all tows. However, any tow with a duration greater than or equal to 10 minutes was also considered successful. Sampling was conducted on a 24 hour basis.

The trawl bottom touchdown, i.e., start of tow, was monitored real time with a Furuno® trawl eye mounted on the headline of the trawl. Trawl geometry was monitored through a combination of the trawl eye and Scanmar spread sensors mounted in the doors. In 2009, Marport® spread sensors in stainless-steel protective canisters were mounted at the wing tips to get direct measurements of wing spread. A Marport MBAR records all trawl geometry as well as GPS speed for the determination of swept area.

The swept area of each tow was determined through the multiplication of speed, bottom time and wing spread. Prior to 2008, speed was determined from the average of five GPS speeds recorded on deck sheets distributed evenly over the 15 minute duration of the tow. From 2008 onward, the average of all speeds from GPS GPRMC strings recorded by Marport over the duration of the tow was used. Wing spread was determined either through direct measurement (2010 onward) or by conversion from door spread through the formula derived from Cosmos model tested in a flume tank (Siferd 2010) when direct measurements were not available. All available wing spread measurements (direct or derived) were averaged over the duration of the tow. Bottom time was determined from depth-time recordings from a trawl mounted Starr-Oddi® (2006) or Seabird CTD (2007) or Marport recordings of the Furuno trawl eye (2008 onward).

Water temperatures were measured on each tow of the survey. In 2006, a Starr-Oddi DST-CTD set at a 1 second sampling interval was mounted on the headline and/or the trawl door. Starr-Oddi measurements were inter-calibrated with Seabird CTD during vertical profiling operations. Temperature was corrected to the Seabird equivalent. After 2006, a Seabird 19plus CTD was mounted at the center of the headline. Bottom temperature was considered the average of all measurements taken between the start and end of the tow while the trawl was on bottom.

In 2014, the WAZ was surveyed in conjunction with the NSRF-DFO survey of the EAZ and completed between 27 August and 3 September. The same strata used in the previous DFO surveys were used. However, the *Kinguk* could not fish the deepest 750-1000 m stratum requiring that it be dropped in this and future surveys of the area. Sample allocation remained as with the DFO surveys, i.e., buffered random sampling, but with three extra sites selected to act as alternates required by the NSRF-DFO survey protocols. Otherwise the survey procedures are identical to those described previously for the EAZ.

CATCH PROCESSING

Catch in all survey areas were processed in the same manner. From the catch, a random shrimp sample containing up to approximately 300 individuals was sorted to species. Northern Shrimp and Striped Shrimp were further divided into male, transitional, primiparous, multiparous or ovigerous stages based on characteristics according to Rasmussen (1953), Allen (1959) and McCrary (1971). These stages were further divided into batches by disease condition, carapace condition and whether head roe was present. Each batch was weighed to the nearest 0.0001 kg. The oblique carapace length (CL) of all Northern Shrimp and Striped Shrimp individuals within each batch was measured by digital calipers and electronically recorded to the nearest 0.01 mm.

At the Freshwater Institute in Winnipeg, juvenile shrimp samples were thawed, weighed then divided into component parts and shrimp processed as described above. All other components were broken down to species, weighted and counted.

BIOMASS ESTIMATION

Three categories of biomass for Northern Shrimp and Striped Shrimp were calculated from the observed survey catch; total, fishable and female spawning stock. Total biomass includes all individuals. Fishable biomass is considered to be all females and all males greater than 17 mm CL. Female spawning stock biomass (SSB) is all females present in the catch.

Regardless of the type of biomass, the estimate was calculated in the same way. Shrimp of a particular species and biomass type caught at a sampling station in kilograms per square kilometer was calculated as:

$$ShrimpCatch = \frac{ShrimpWt \times BumpFactor}{SweptArea}$$

The Bump Factor is the ratio used to raise the shrimp sample to that of the full catch for the station.

Catch from the survey is processed in two ways. If all shrimp from the catch are sampled then:

$$Bump\ Factor = Shrimp\ Sample\ Ratio \times Process\ Ratio$$

Otherwise, if the shrimp came from a subsample of the total catch then this is referred to as coming from Mix Catch requiring additional factors required to bump to the full catch:

$$Bump\ Factor = Shrimp\ Sample\ Ratio \times Process\ Ratio \times Mixed\ Catch\ Ratio \times Catch\ Process\ Ratio$$

where,

$$Shrimp\ Sample\ Ratio = \frac{Shrimp\ Sample\ Weight}{Shrimp\ Subsample\ Weight}$$

$$Process\ Ratio = \frac{Shrimp\ Subsample\ Weight}{\sum_j Separate\ Shrimp\ Species\ Weights}$$

$$Mixed\ Catch\ Ratio = \frac{Mixed\ Weight}{Mixed\ Subsample\ Weight}$$

$$Catch\ Process\ Ratio = \frac{Mixed\ Subsample\ Weight}{\sum_j Separate\ Species\ Weights}$$

where,

Catch Weight is the portion of the catch weighed as a whole prior to sorting,

Subsample Weight is the portion of catch randomly selected to be sorted into j component parts, usually species or higher group, each weighed separately,

Shrimp Sample Weight is the weight of all shrimp sorted from the total catch or subsampled catch,

Shrimp Subsample Weight is the portion of the Shrimp Sample before it is sorted into single shrimp species,

Shrimp Species Weight is the total weight of an individual shrimp species.

The biomass estimates for the survey area are calculated by:

$$Biomass = \sum_{k} \left(\frac{\sum_{s} Shrimp\ Catch_{st}}{n_t} \right) \times Stratum\ Area_t$$

where,

s is one of n stations sampled in stratum t of which there are k strata within the survey area.

Upper and lower confidence intervals (CI) were estimated by resampling statistics (Bruce et al. 2000). CIs reported in the 2008 and 2010 Science Advisory Reports (DFO 2008; DFO 2010) were a summation of all individual stratum CIs in the survey area. The 2011 ZAP concluded this was not the correct approach. The approved method was to resample from the observed catch with replacement to produce a biomass estimate for the survey area as described above. A set of 15,000 estimates was produced from additional runs based on a new sampling of the observed catch with replacement, then sorted in ascending order. The estimate at the 2.5 and 97.5 percentiles of all runs were considered the 95% CI for the biomass estimate.

PRECAUTIONARY APPROACH FRAMEWORK

Shrimp in the EAZ are assessed with in a Precautionary Approach Framework (DFO 2007b) with reference points developed during two workshops which included Science, Fisheries Management and stakeholder representatives (DFO 2009). The Upper Stock and Limit Reference Points agreed to were 80% and 30% of the geometric mean of female spawning stock biomass. The reference points were first developed for SFA2 and included three surveys conducted in 2006-2008. The SFA2 reference points were transferred unchanged for the EAZ at the 2011 ZAP.

TEMPERATURE

Contour plots of bottom temperature were produced by kriging mean bottom temperature data collected at each station using Surfer® Ver. 8 (Golden Software 2002).

COMMERCIAL FISHERY DATA

Catch per Unit Effort (CPUE) was calculated from observer catch data for directed fishing of Northern Shrimp or Striped Shrimp. Catch was the total catch, retained and discarded, reported. Effort was the total number of hours the trawl was towed. Effort of twin or triple trawls was considered as two or three times, respectively, the tow time recorded. Standard parametric statistics were used to produce an average CPUE and 95% CI by management year within each assessment area.

RESULTS AND DISCUSSION

BOTTOM TEMPERATURE

Area-weighted mean bottom temperatures for the EAZ and its component survey areas increased by over a degree from the 2009 to 2010 (Figure 4a and 4b). Since then the EAZ temperature has been declining each year and is now at levels similar to that seen during the first four years of surveys. With its larger area, the EAZ index closely follows that seen in the SFA2EX index (Figure 4a). In RISA, RISA-E has been 1.5°C warmer than RISA-W while showing similar changes over the time series (Figure 4b). The high temperature jump in 2010/2011 was greater in RISA-W but the drop after 2011 was also greater.

Other than survey timing, the change in survey in the WAZ should have no effect on the time series of mean bottom temperatures. It would appear that the WAZ underwent a similar pattern of temperature change as seen in the EAZ but the biennial sampling may mask other changes in non-survey years (Figure 4c). In 2014, the WAZ was about a degree colder than RISA-W and over two degrees colder than RISA-E.

EASTERN ASSESSMENT ZONE

Survey Area Results

In 2013, the survey was conducted aboard the fishing vessel *Aqviq*. The crew first completed the survey of RISA from 27 July to 2 August then completed SFA2EX between 2 August and 17 August. All 60 stations allocated to the two RISA survey areas were sampled as were the 121 stations allocated to SFA2EX (Figure 5).

In 2014, the fishing vessel *Aqviq* became unserviceable prior to the survey. This required it to be replaced with her sister ship *Kinguk*. Mechanical problems encountered during the survey of SFA 4 required the *Kinguk* to return to Newfoundland for repairs. SFA 4 and the WAZ were completed first resulting in the survey of the EAZ starting and ending about a month later than normal. The survey began in SFA2EX on 3 September and was partially completed by 14 September when the survey of RISA began to take advantage of the neap tide. RISA was surveyed until 16 September when the *Kinguk* had to sail to Nuuk, Greenland to refuel. Upon return, SFA2EX was completed between 19 and 20 September after which RISA was completed between 21 and 24 September. 115 of the 121 stations allocated in SFA2EX design were successfully sampled (Figure 6). The 750 m stratum 070 was missed completely but because it generally does not contribute greatly to biomass this is unlikely to have an effect on overall results. Only 51 of the 60 stations allocated in the RISA design were sampled.

SFA2EX *P. borealis* Biomass and Distribution

In 2013 and 2014, the distribution of *P. borealis* catch (Figure 5 and 6) has remained consistent with that seen in previous surveys. The main concentrations have been found in more or less a continuous band which follows the 300-400 m strata. The 100-200 and 500-750 m contribute very little to the overall survey area biomass. The main concentration of *P. borealis* mostly occurred in water of 2 to 3°C in 2013 (Figure 7), but in 2014 the water temperature was mostly 1 to 2°C (Figure 8).

Total, fishable and female SSB indices appear fairly stable from 2007 to 2012 but showing a decline in biomass over the last two year of the time series although there is no significant difference in year to year estimates (Figure 9). Total and fishable biomass indices are now at their lowest level in the time series.

SFA2EX *P. montagui* Biomass and Distribution

In 2013 and 2014, only small catches of *P. montagui* were taken in SFA2EX mainly in the southwest part of the survey area (Figure 10 and 11), a pattern consistent with previous surveys. The species is mostly found in the inshore 200-400 m depth strata. *P. montagui* are found in water of -1 to1°C with the larger catches coming from water 0 to 1°C (Figure 12 and 13).

With the exception of 2009, total, fishable and female SSB biomass indices of *P. montagui* have been consistently low (<2000 t; Figure 14).

RISA *P. borealis* Biomass and Distribution

The largest catches of *P. borealis* came from the western side of RISA-E near Resolution Island in 2013 (Figure 15) and 2014 (Figure 16). As a consequence, the majority of the RISA *P. borealis* biomass came from RISA-E (Figure 17) with a smaller contribution from RISA-W (Figure 18). Biomass in RISA-E was higher for the period 2009-2011 but for the past three year 2012-2014 was at levels comparable to 2008. RISA-W shows an opposite trend (Figure 18). Most the *P. borealis* in RISA are found in water temperature between 1 and 4°C with the largest sets coming from waters of 1 to 2°C (Figure 7 and 8).

RISA *P. montagui* Biomass and Distribution

By far the large catches of *P. montagui* were found in RISA-W west of the Button Islands and Resolution Island in 2013 (Figure 19) and 2014 (Figure 20) consistent with previous surveys. In RISA-W, *P. montagui* are predominantly found in shallower strata of 200-300 m. These depths relate to cooler waters (<1°C) preferred by *P. montagui* (Figure 12 and 13).

P. montagui biomass was trending downward in RISA-E for the years 2008-2013 but showed a slight increase in 2014 (Figure 21). In RISA-W, *P. montagui* biomass had been stable from 2008 varying without trend until the 2012 survey where it sharply increased to about four times the next highest biomass observed in the time series (Figure 22). At that time this large increase was considered a year-effect (Siferd 2014). In 2013, the biomass decreased, sharply and significantly, returning to what appeared to be a more "normal" level in line with what had appeared to be a slowly declining resource. The biomass again increased significantly in 2014 but only to about half that seen in 2012. This makes the conclusion that the 2013 was a year-effected survey dubious. It seems more likely now that what is being observed is movement of shrimp into and out of RISA-W. Certainly other theories could be put forward that could explain the time series.

Assessment of the EAZ

Eastern Assessment Zone – P. borealis

Total, fishable and female SSB indices of *P. borealis* in the EAZ have hovered around their long-term means from 2008-2014 (Figure 23 and Table 1). However, total and fishable biomasses had been above the mean of 64,444 t and 62,682 t respectively for the period 2009-2011 but were below the mean for the subsequent three years. The 2014 estimate of fishable biomass was 50,458 t. Similarly female SSB was above its long-term mean of 37,918 t for the period 2009-2012 but below the mean in the last two years. Female SSB was estimated to be 34,069 t for 2014.

Recruitment of *P. borealis* in the EAZ is uncertain (Figure 24) because very few individuals between 11.5 and 17 mm are collected within the cod end of the Campelen trawl (Figure 25). The signal from the Linney Bag attached to the outside of the trawl indicates a greater proportion of pre-recruit sized shrimp are present in the system than seen from the cod end catch (Figure 26). Even so, strong pre-recruit signals such as seen in 2006 which translated to a strong class in the following year are rare in the survey series and so the relationship between recruitment and female spawning stock cannot be determined.

The proportion of male and female *P. borealis* in the EAZ population was examined (Figure 27). Given the under representation of males seen in the cod end frequency curves (Figure 26), the ratio of males to females would be biased toward females. While there are differences in the proportions in some years, there is no overall trend apparent in the time series (Figure 27) and it would appear that the EAZ has a healthy sex ratio. This is in contrast to that seen in the West Greenland Northern Shrimp stock (Michael Kingsley, pers. comm.) where females are now

making up the bulk of the population which is not conducive to a sustainable shrimp stock. No such problem currently exists in the EAZ.

Commercial fishing in the EAZ began in the late 1970s in the northeast of SFA2EX. Catch was low until 1988. A quota of 3,500 t was introduced in 1989 (Table 3; Figure 28). Catch declined to near zero in 1993 after which it increased steadily for the next four years as the captains learned where to best prosecute the fishery in SFA2 i.e., in the area east of Resolution Island. In 1997, the quota was increased by 1,750 t which increased catch to 6,359 t that year. Catches have remained relatively stable fluctuating near 6,000 t through the 2009/10 fishing season. Increased effort in SFA2EX saw the catch in the EAZ reach an all-time high in 2011/12 of 7,423 t. The bulk of the catch each year is taken from a very small area east of Resolution Island. In most years the fishery, in what is now known as Davis Strait-West, takes most of the quota assigned to that management unit. How much more of the EAZ TAC is taken each year is dependant mainly on the industry locating commercially exploitable concentration of shrimp in Davis Strait-East.

Dividing the reported catch by the fishable biomass produces an exploitation rate for the zone (Figure 29). Two rates, reported and potential, have been calculated for the EAZ because over the history of the fishery, TAC has rarely been taken and has never since survey data became available for comparison. The reported exploitation rate has varied without trend with a mean of 9.9% from 2008/09 onward (Figure 29a) and was at the long term mean in 2014/15. If the EAZ TAC had been taken, it would have resulted in a higher exploitation rate mean of about 14.8% over the same period (Figure 29b). The potential exploitation rate for 2014/15 was 16.4%.

The composition of the catch in the EAZ had been predominantly female from 2005/06 to 2014/15 (Figure 30). For fishing seasons 2010/11 through 2012/13, however, the composition was nearer to equal proportions of males and females. Size ranges of shrimp caught over the years appear to be stable. Only 6 sets from the 2014/15 were available for analysis and so should be interpreted with caution.

The *P. borealis* resource remains well within the Healthy Zone of the PA Framework established for the EAZ (Figure 31). The current TAC would produce an exploitation rate of about 16.4% up from previous assessments but below the maximum removal reference of 20% for the Healthy Zone.

Eastern Assessment Zone – P. montagui

With RISA-W being the largest contributor to the overall *P. montagui* resource, fluctuations seen there in the past four years naturally translate into wide fluctuations to the overall EAZ *P. montagui* biomass indices (Figure 32). At the 2013 ZAP, it seemed logical to suspect the 2012 was simply a year-affected survey (Siferd 2014). Therefore at that time, it was advised that the point be ignored (DFO 2013). The 2013 survey that followed seemed to confirm this advice when the biomass estimates for 2013 seemed to return the EAZ to a slowly declining trend in female SSB (DFO 2014). However, with the significant increase in biomass again in 2014, one must now be less certain that we are witnessing year effects over the past four years. These wide fluctuations in biomass make interpretation of the time series difficult and therefore the status of the stock uncertain.

The survey design is appropriate for an assessment survey and the same as used in other Shrimp Fishing Areas (SFAs) so there is no reason to suspect the basic survey design as the cause of the fluctuations. However, surveying within the highly energetic survey areas of RISA (Drinkwater 1986, Hudon 1990) is known to affect fishing as evidenced through comments by industry and personal experience. Sampling RISA during the neap tide is an attempt to minimize the variability. While this would help for some stations, when fishing 24 hours a day there are

still times when current is very strong. The effect of this on results has not been quantified but may be one possible source of the fluctuations. Another possibility, which seems more plausible, is that given the highly energetic area and the large *P. montagui* population just to the west of RISA-W, the fluctuations could indicate shift in distribution. It is easy to imagine this shift is quite possible, given the small area involved. With a single sampling of the area each year we have no way of knowing what the distribution is over a full year.

P. montagui recruitment (Figure 33) in the EAZ is uncertain for the same reasons stated previously for *P. borealis*; however the proportion of recruitment sized individuals appears greater for *P. montagui* (Figure 34). In the Linney Bags, *P. montagui* show a stronger signal of recruit and pre-recruit sized shrimp (Figure 35) although no young-of-the-year were found in the samples. The relative abundance of males and females appear to alternate yearly in the survey series (Figure 34). This seems to indicate male conversion to females does not occur regularly but in a biennial fashion. It is unknown whether this is a sampling artifact or a life history characteristic in the EAZ. To my knowledge this has not been seen in other *P. montagui* populations though this species is rarely studied when compared to *P. borealis*.

The proportion of male and female *P. montagui* in the EAZ population was examined (Figure 36). Given the under representation of males seen in the cod end frequency curves (Figure 35), the ratio of males to females would be biased toward females. No trend is apparent in the time series although the proportions fluctuate wildly from year-to-year. While there are differences in the percent composition in some years, overall, it would appear that *P. montagui* in the EAZ has a healthy sex ratio.

The fishery in the EAZ began with an initial quota of 100 t in 1978 and the first catch reported in 1979 (Figure 37). Quotas have increased several times and new access added through special allocations since then but catch has rarely matched the available quota in the zone. It is unclear whether the large catch over-runs in 1995-1997 are real because of discrepancies between Canadian Atlantic Quota Report (CAQR) reported catch and observer records. There was a general decline in catch from about the year 2000 to 2011/12. Since much of the quota for *P. montagui* is considered by-catch taken during the prosecution of the *P. borealis* fishery, two factors are believed to contribute to the decline in catch. First, fishing captains indicate increased knowledge of indicators such as water temperature and seasonality that affect shrimp distributions i.e., they have learned to be able to avoid *P. montagui* using these indicators. Second, the Nunavut Land Claims Agreement came into effect in 1999 which placed a new jurisdictional boundary within SFA2. This boundary moved the offshore industry fleet to the east of where they had normally fished. Given the distribution of *P. montagui* this moved the fleet into waters where this shrimp was less abundant, naturally reducing its by-catch as a result. Therefore the reduction in catch is not believed to be an indicator of stock status. The increase seen in 2012/13 is mainly a result of additional effort in the EAZ south and west of Resolution Island. This stems from survey results in the WAZ to the west and changes coming into effect for the management of the shrimp fishery within the region. A new management system came into effect in 2013/14 which reduced the TAC in accordance with the observed biomass from the surveys. The TAC was further reduced for 2014/15 based on the reduced biomass while discounting the 2012 survey result. The recent fluctuations observed do not negate the decision but indicate that caution in setting new TACs is warranted given the uncertainty in the status of the resource in the EAZ.

Comparing the *P. montagui* catch in the EAZ to its fishable biomass produced a reported exploitation rate with a long term mean of 8.3% from 2008/09 to 2014/15 (Figure 38a). The potential exploitation rate, based on the summation of all quotas in the zone, has a much higher mean of 47.3% over the same time period (Figure 38b). The exploitation rate index is strongly affected by the fluctuation in fishable biomass observed over the past four years. Currently in

2014/15 the reported exploitation rate index is very low at 2.4% and the potential based on the EAZ TAC is about double that amount, 5.1%. Both are well below the long term mean of the time series.

The fluctuations in *P. montagui* female SSB has resulted in the placement of the resource from just above the Limit Reference Point to well above the Upper Stock reference repeatedly over the past four years (Figure 39). Great caution must be taken in interpreting this as a significant change in the status of *P. montagui* in the EAZ given the uncertainty in the female SSB index.

Reference Points

Some caution should be taken when interpreting the EAZ PA Frameworks. The reference points were based on the 2006-2008 survey results. This is a short time series with the first two years now considered invalid in the time series because of performance issues set coverage in the initial surveys conducted in RISA in 2006 and 2007. Without the historical context of a longer time series it is unknown whether the EAZ is currently within a productive period or not. In addition the reference points were developed for SFA2 not the EAZ. New reference points should be developed representative of the EAZ based on the most reliable data available.

Commercial Fishery Data

CPUE was low in the first decade or so of the fishery for *P. borealis* in the EAZ (Figure 40). As quotas increased and the most productive fishing locations found, CPUE increased steadily from 1994 to 2000 where it leveled off through to the 2008/09 fishing season. CPUE has continued on a generally increasing trend through to the 2013/14 fishing year. The large drop in CPUE in the 2014/15 season was not recognised by industry. Very few observer records were available for this assessment and it will not be known whether this is real until all the records become available.

The CPUE from the *P. montagui* fishery in the EAZ is shown in Figure 41. No directed *P. montagui* records were available for the 2014/15 fishing year. *P. montagui* fishing in the EAZ is a mix of directed and by-catch fishing. Changes in the price differential of the two shrimp species and their marketing make CPUE problematic to calculate and especially hard to interpret. Apparently, observers record the directed species of a set based on which species exceeds 50% of the shrimp catch. Since CPUE only makes sense in a directed fishery, *P. montagui* by-catch is left out of the overall CPUE calculation.

CPUE is included here as industry requests the information. It is not believed to indicate status of either shrimp species resource but rather is more reflective of fishing behaviour within the EAZ.

WESTERN ASSESSMENT ZONE

Survey Area Results

The first NSRF-DFO conducted survey of the WAZ was completed between 27 August and 3 September 2014. 70 stations were allocated to the survey area as was done with the DFO surveys. However, the *Kinguk* was unable to sample the two stations in the 750-1000 m stratum C7-1 (Figure 42). Because the stratum is beyond the capacity of the ship, it was removed from the survey design for this and future surveys of the area. Further, since this marks the start of a new time series dropping C7-1 from the design will have no effect going forward. 57 of the 68 remaining stations allocated were successfully taken. The majority of stations not sampled came in large stratum C2-1, a 100-200 m stratum in Ungava Bay, where 12 of the 20 stations allocated were taken. Finding trawlable bottom was cited as the reason for the missed stations. While sufficient stations were sampled within C2-1 to produce an acceptable biomass figure,

sampling was biased toward the eastern side of the stratum. Given the distributions seen in DFO surveys of the area this could inflate the biomass estimates for the stratum but would not significantly affect the overall WAZ biomass estimate. Two additional strata, C3-1 and C3-3, were short of their six allocated stations by one and two stations, respectively. This should have no effect on the biomass estimated for these strata.

Bottom Temperature

Area-weighted mean bottom temperature should only be affected by the timing of the surveys and not by the survey gear or the ship used, making the series more comparable. Bottom temperature in the WAZ averaged about 0.5°C in 2007 and 2009, increased to 1.5°C in 2011 then returned to earlier levels in 2013 (Figure 4c). Timing of the surveys does not seem a factor as the first two surveys were at similar times but the last two were a several weeks earlier. In 2014, the area was the coldest of the time series with a mean of 0.16°C even though the survey was conducted approximately a month earlier than all the previous surveys.

Western Assessment Zone –*P. borealis*

The main catches of P. borealis are found in Hudson Strait, in the northern portion of the WAZ (Figure 42). This corresponds with the tongue of warm water (>0°C) extending into the strait (Figure 43). Although *P. borealis* can be found in water below 0°C, 16 of the 23 stations sampled in 2014 were below 0°C and had no *P. borealis*. The remaining samples had only small catches.

Total, Fishable and Female Spawning Stock biomass indices are shown in Table 5 and Figure 44. Although previous surveys conducted by DFO are included, they are not considered comparable to the start of the new time series. In 2014, the total biomass was 22,674 t, fishable biomass was 21,712 t and female spawning stock biomass was 12,209 t.

Prior to the 2013/14 fishing year, the only quota for *P. borealis* was the by-catch quota of 400 t (Figure 45). For the 2013/14 fishing year a new management system was implemented which included new SFAs subdivided further into management units. The WAZ has two management units Nunavut-West and Nunavik-West which are fully within the two land claims areas (Figure 1). The initial TAC for the WAZ was set at 3,000 t for 2013/14 and was divided into equal shares of 1,500 t for Nunavut and Nunavik. By agreement, they can be fished anywhere within either land claims area (Table 3 and Figure 45). The TAC was increased in 2013/14 to 2,080 t.

In 2013/14, 62% and in 2014/15 41% of the TAC was taken (Figure 45). Even though the TAC was not been taken this does not reflect the status of the stock in the areas. Fishermen report that is it difficult, if not impossible, to find areas that have clean or even high percentages of *P. borealis* within the WAZ making it hard to direct for the species. Once the TAC for *P. montagui* has been taken, fishing ceases in the WAZ resulting in the *P. borealis* catch remaining short of the TAC. As a consequence, the reported exploitation rate index was low, at 3.9% for 2014/15 (Figure 46a). The potential exploitation rate index was 6.9% (Figure 46b), i.e., if the TAC had been taken. This rate is conservative in comparison to other SFAs surveyed with the same gear. While additional experience in the area by the fishing fleet may change this, taking the *P. borealis* TAC is more likely to be accomplished by increasing the TAC of *P. montagui* alone. Increasing the TAC for both species could increase the total catch of *P. borealis* but it would still very likely remain below the TAC.

Western Assessment Zone –*P. montagui*

The largest catches of *P. montagui* are found in Hudson Strait and the northeast corner of Ungava Bay (Figure 47). They are highly mixed with *P. borealis* in the WAZ but *P. montagui*

tend to prefer cooler waters (Figure 48). In 2014, the majority of large catches were taken in water with temperatures of 0 to 1°C.

Total, Fishable and Female Spawning Stock biomasses are shown in Table 5 and Figure 49. Although previous surveys conducted by DFO are included, they are not considered comparable to the start of the new time series. Total biomass in 2014 was 86,239 t, fishable biomass 77,078 t and female spawning stock biomass 38,875 t.

From 1979 through 1991 only six years had catch recorded in what is known as the WAZ. Over the next two decades no catch was recorded until the 2010/11 fishing year after the DFO surveys in 2007 and 2009 renewed interest in the area (DFO 2008; 2010). Catch increased in the following two seasons but jumped significantly when the new management system was implemented in 2013/14. In 2013/14, 4,867 t of the new 5,000 t TAC was taken. The TAC was increased to 5,860 t for the 2014/15 fishing year and 5,836 t taken. With the TAC taken the exploitation rate index was 6.3% (Figure 51). The harvest rate is low in comparison to other SFAs but is in keeping with the desire to develop the fishery slowly expressed by all stakeholder and DFO when the new management system was developed.

Reference Points

Reference points for the WAZ had been created based on results from the biennial DFO surveys in 2007-2011 (Siferd 2014). With the WAZ now being surveyed in conjunction with the NSRF-DFO survey this has reset the time series. Since no standardization of the surveys has taken place, results from the two surveys cannot be compared making the PA framework, developed previously, no longer valid for the new time series. At least three to four more successfully completed surveys are required before new reference points could be calculated for the WAZ.

Commercial Fishery Data

The WAZ has been fished sporadically from 1979-1991 and not again until the 2010/11 fishing season but effort has increased significantly since. CPUE increased significantly from 2010/11 reaching a peak in 2012/13 (Figure 52). However, in the last two years CPUE has dropped off. Very few observer records were available for this assessment and so the 2014/15 value should be viewed with caution and likely does not truly reflect fishery performance in the current fishing season. Fishermen indicate that this is, at least in part, due to their trying to locate cleaner catches of *P. borealis* and less to do with the abundance of shrimp in the area.

FUTURE ASSESSMENTS

Changes in the survey plan implemented by the C&A Region in 2014 may, in the future, help elevate the uncertainty in assessment of stock status for both Pandalid species, especially for *P. montagui* in the north. Having all survey areas (2G, SFA2EX, RISA and the WAZ) sampled with the same ship, gear and at the same time of the year will allow the different survey areas to be combined and assessed as a unit. It seems most logical that the stock area be designated as all areas now surveyed by NSRF-DFO. Combining the areas of SFA4, the EAZ and WAZ into one large assessment zone would better reflect the "true" stock area for both Pandalid species for the purpose of determining stock status. Issues around the transport of both Pandalid shrimp species (e.g., biomass fluctuations, adult transport/distribution and determination of female SSB) occur between all of these survey areas which may be eliminated by combining the smaller "stock" areas into one zone. As the time series in the WAZ was restarted in 2014, more surveys are needed for the time series to build into a more reliable index of the whole population. Future assessments of this combined area would be best handled by having a

designated expert conduct the assessment for this larger area rather than combining separate assessments of the regional components of the area.

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TABLES AND FIGURES

Table 1. Total, fishable and female spawning stock biomass indices estimates for Pandalus borealis *in the Eastern Assessment Zone for the 2006-2014 surveys. LCL and UCL represent the 95% confidence range.*

		Weight (tonne)		
Year	Biomass	Mean	LCL	UCL
2014	Total	51409.71	39659	63161
2013	Total	50421.46	38679	61927
2012	Total	60985.45	43497	80408
2011	Total	83461.84	23956	143793
2010	Total	71887.38	41392	108846
2009	Total	81363.27	51479	113556
2008	Total	51581.26	37757	67137
2007	Total	43827.19	31480	58333
2006	Total	33633.55	22700	45511
2014	Fishable	50457.99	38914	62340
2013	Fishable	49696.90	38427	60631
2012	Fishable	60533.67	43074	79960
2011	Fishable	78530.23	23900	135037
2010	Fishable	71064.51	40234	108703
2009	Fishable	78754.88	48850	110115
2008	Fishable	51053.43	37117	66708
2007	Fishable	43305.97	31015	58346
2006	Fishable	32815.89	21969	44152
2014	Female SS	34069.42	25157	43000
2013	Female SS	32049.10	26762	37607
2012	Female SS	41189.85	29498	54383
2011	Female SS	47806.80	13470	82926
2010	Female SS	43800.31	19025	79665
2009	Female SS	38856.32	23122	56820
2008	Female SS	27653.12	22507	39368
2007	Female SS	27698.44	19249	39007
2006	Female SS	16805.06	10523	23026

Table 2. Total, fishable and female spawning stock biomass indices estimates for Pandalus montagui *in the Eastern Assessment Zone for the 2006-2014 surveys. LCL and UCL represent the 95% confidence range.*

		Weight (tonne)		
Year	Biomass	Mean	LCL	UCL
2014	Total	17589.36	11922	23295
2013	Total	3651.01	1822	6367
2012	Total	29966.61	8922	50956
2011	Total	8729.02	3266	16395
2010	Total	7860.38	6089	9795
2009	Total	17437.62	7427	32323
2008	Total	16088.04	8421	23642
2007	Total	7587.20	4378	11042
2006	Total	2833.27	255	5412
2014	Fishable	16599.97	11203	22084
2013	Fishable	3524.28	1738	6208
2012	Fishable	28845.47	8582	48946
2011	Fishable	7739.99	2871	14285
2010	Fishable	7422.75	5714	9290
2009	Fishable	15679.12	6190	29774
2008	Fishable	14667.04	7287	21973
2007	Fishable	4828.25	3389	6673
2006	Fishable	2667.14	210	5122
2014	Female SS	12696.30	8834	16622
2013	Female SS	2777.54	1301	4949
2012	Female SS	23552.02	6218	40985
2011	Female SS	3124.24	1599	4721
2010	Female SS	5819.1	4509	7136
2009	Female SS	8775.54	4205	13955
2008	Female SS	10659.82	4269	17047
2007	Female SS	1970.63	903	3490
2006	Female SS	2134.38	50	4219

Table 3. Quota, adjusted quota (after bridging) and catch (t) reported by CAQR for Pandalus borealis *in SFA 2 and 3 1988-2012/13 after which the area was converted to SFA Davis Strait (DS), Nunavut (NU) and Nunavik (NK).*

	Shrimp Fishing Area or Quota Area								
	SFA2EX			SFA2CM			SFA3[2]		
Management Year[1]	Initial Quota	Adjusted Quota	Catch	Initial Quota	Adjusted Quota	Catch	Initial Quota	Adjusted Quota	Catch
1988						2826			
1989				3500		3039			
1990				3500		1771			
1991				3485		1098			
1992				3485		1239			
1993				3485		106			
1994				3500		475			
1995				3500		2721			
1996				3500		3968			
1997				5250		5235			
1998				5250		5163			41
1999	3500	3500	105	5250	5250	5027			0
2000	3500	3500	237	5353	5353	4024			0
2001	3500	3500	394	5250	5250	5435			0
2002	3500	3500	64	5250	5250	5533			0
2003/04	3500	3500	31	5250	5250	4792			0
2004/05	3500	3500	212	5250	5250	5019			0
2005/06	3520	3520	736	5253	5253	5466			0
2006/07	3480	3480	725	5247	5247	5241	400	400	90
2007/08	3500	3500	529	5250	5250	5781	400	400	406
2008/09	3500	3500	213	5250	5192	4898	400	400	0
2009/10	3500	3465	1030	5250	4660	4399	400	400	0
2010/11	3500	3483	802	5250	5797	5721	400	400	53
2011/12	3500	3201	2557	5250	5302	5298	400	400	161
2012/13	3500	3763	654	5250	5329	4666	400	400	246

	Shrimp Fishing Area or Management Unit								
	Davis Strait - East			DS- W + NU-E + NK-E			NU-W + NK-W		
Management Year	Initial Quota	Adjusted Quota	Catch	Initial Quota	Adjusted Quota	Catch	Initial Quota	Adjusted Quota	Catch
2013/14	3500	3157	978	5500	6166	6132	1500	1500	933
2014/15[3]	3208	3208	105	5042	5042	4867	2080	2080	847

[1] Management Year changed from calendar to fiscal in 2003. 2003/04 season 15 months during the conversion period.

[2] *P. borealis* by-catch to be fished within SFA3 and SFA2 within the NSA while directing for *P. montagui*.

[3] CAQR as of 25 January 2013 may be incomplete as fishery is on-going.

Table 4. Quota, adjusted quota (after bridging) and catch reported by CAQR for Pandalus montagui *in SFA 2 and 3 1988-2012/13 after which the area was converted to SFA Davis Strait (DS), Nunavut (NU) and Nunavik (NK).*

	Shrimp Fishing Area or Quota Area								
	SFA2[2]			SFA3[2]			2,3,4 Quota[3]		
Management Year[1]	Initial Quota	Adjusted Quota	Catch	Initial Quota	Adjusted Quota	Catch	Initial Quota	Adjusted Quota	Catch
1978							100		0
1979							100		92
1980							200		236
1981							200		13
1982							200		0
1983							850		0
1984							850		0
1985							850		0
1986							850		476
1987							1200		1069
1988							1200		1125
1989							1200		1269
1990							2280		1635
1991							1190		605
1992							1190		0
1993							1190		0
1994							1200		244
1995							1200		245
1996							1200		0
1997							1200		435
1998				500		0	3300	3300	2205
1999				500		0	3300	3300	3714
2000				500		0	3300	3300	3005
2001				500		0	3300	3300	3751
2002	2000	2000	0	1000	1000	0	4300	4300	3369
2003/04	2000	2000	0	1000	1000	0	3800	3800	1053
2004/05	2000	2000	0	1000	1000	0	3300	3300	2069
2005/06	2000	2000	465	1000	1000	176	3300	3300	1658
2006/07	2000	2000	0	1000	1000	264	3300	3300	2167
2007/08	2000	2000	197	1000	1000	341	3300	3300	606
2008/09	2000	2000	0	1000	1000	0	3300	3300	645
2009/10	2000	2000	0	1000	1000	0	3300	3300	480
2010/11	2000	2000	23	1000	1000	310	3300	3094	554
2011/12	2000	2000	23	1000	1000	836	3300	2778	706
2012/13	2000	2000	92	1000	1000	981	3300	3527	1081

	Shrimp Fishing Area or Management Unit								
	Davis Strait			NU-E + NK-E			NU-W + NK-W		
Management Year	Initial Quota	Adjusted Quota	Catch	Initial Quota	Adjusted Quota	Catch	Initial Quota	Adjusted Quota	Catch
2013/14	1100	971	79	1150	1150	871	5000	5000	4775
2014/15[4]	410	410	98	430	430	303	5860	5860	5836

[1] Management Year changed from calendar to fiscal in 2003. 2003/04 season 15 months during the conversion period.

[2] Nunavut special allocation. Quota to be fished in SFA 2 and 3 within the NSA only.

[3] *P. montagui* to be fished by license holders within SFA 2, 3 and 4 west of 63°W.

[4] CAQR as of 22 January 2015 may be incomplete as fishery on-going.

Table 5. Total, fishable and female spawning stock biomass indices estimates for Pandalus borealis *and* Pandalus montagui *in the Western Assessment Zone for the 2007, 2009, 2011 and 2013 surveys conducted by DFO and the 2014 survey by the NSRF-DFO. LCL and UCL represent the 95% confidence range.*

		***Pandalus borealis* Weight (tonnes)**		
Year	**Biomass**	**Mean**	**LCL**	**UCL**
2014	Total	22673.91	14640	32979
2013	Total	22134.74	16029	28386
2011	Total	21491.90	13714	30399
2009	Total	18401.51	8760	30301
2007	Total	16120.80	5497	31243
2014	Fishable	21712.50	14353	31046
2013	Fishable	21998.56	15906	28518
2011	Fishable	19692.10	12468	27961
2009	Fishable	15543.95	7613	25529
2007	Fishable	14614.98	4907	28872
2014	Female SS	12308.93	8792	16398
2013	Female SS	9785.03	7106	12829
2011	Female SS	6376.60	4182	8909
2009	Female SS	3839.38	1154	7479
2007	Female SS	3231.03	1687	5361

		***Pandalus montagui* Weight (tonnes)**		
Year	**Biomass**	**Mean**	**LCL**	**UCL**
2014	Total	86239.33	50609	12516
2013	Total	50272.52	36664	65238
2011	Total	77142.30	45030	121559
2009	Total	65044.31	31655	112124
2007	Total	78064.38	19755	155041
2014	Fishable	77077.74	44854	111562
2013	Fishable	45647.22	32899	59438
2011	Fishable	71557.90	40264	108612
2009	Fishable	46672.87	25756	73342
2007	Fishable	54044.48	17007	99461
2014	Female SS	38875.39	23553	55849
2013	Female SS	26955.19	18616	35736
2011	Female SS	32549.40	20296	46119
2009	Female SS	17998.70	9775	28160
2007	Female SS	19277.30	5668	36606

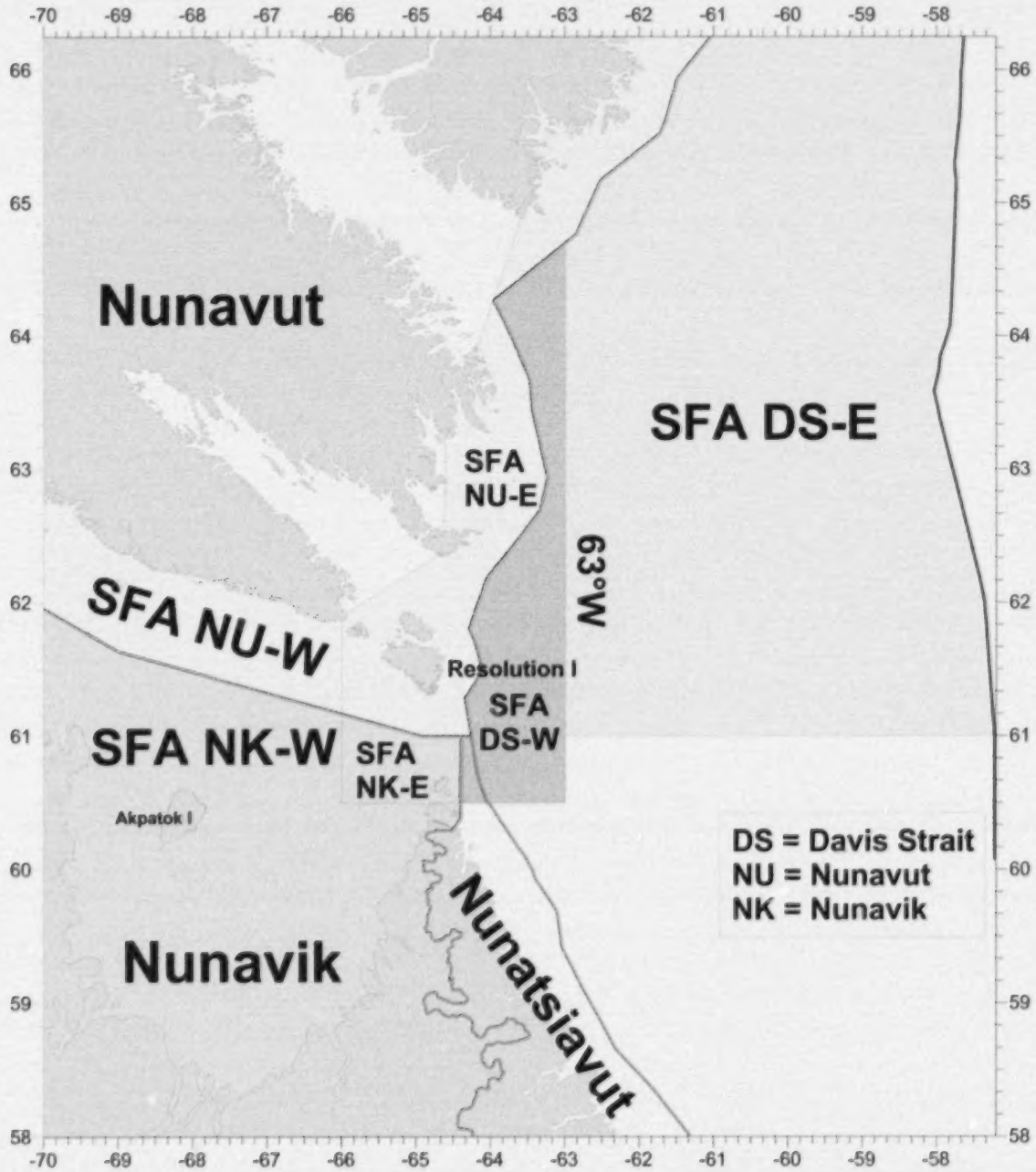

Figure 1. Shrimp Fishing Areas Nunavut (NU), Nunavik (NK) and Davis Strait (DS) and their East and West management units within DFO's Central and Arctic Region.

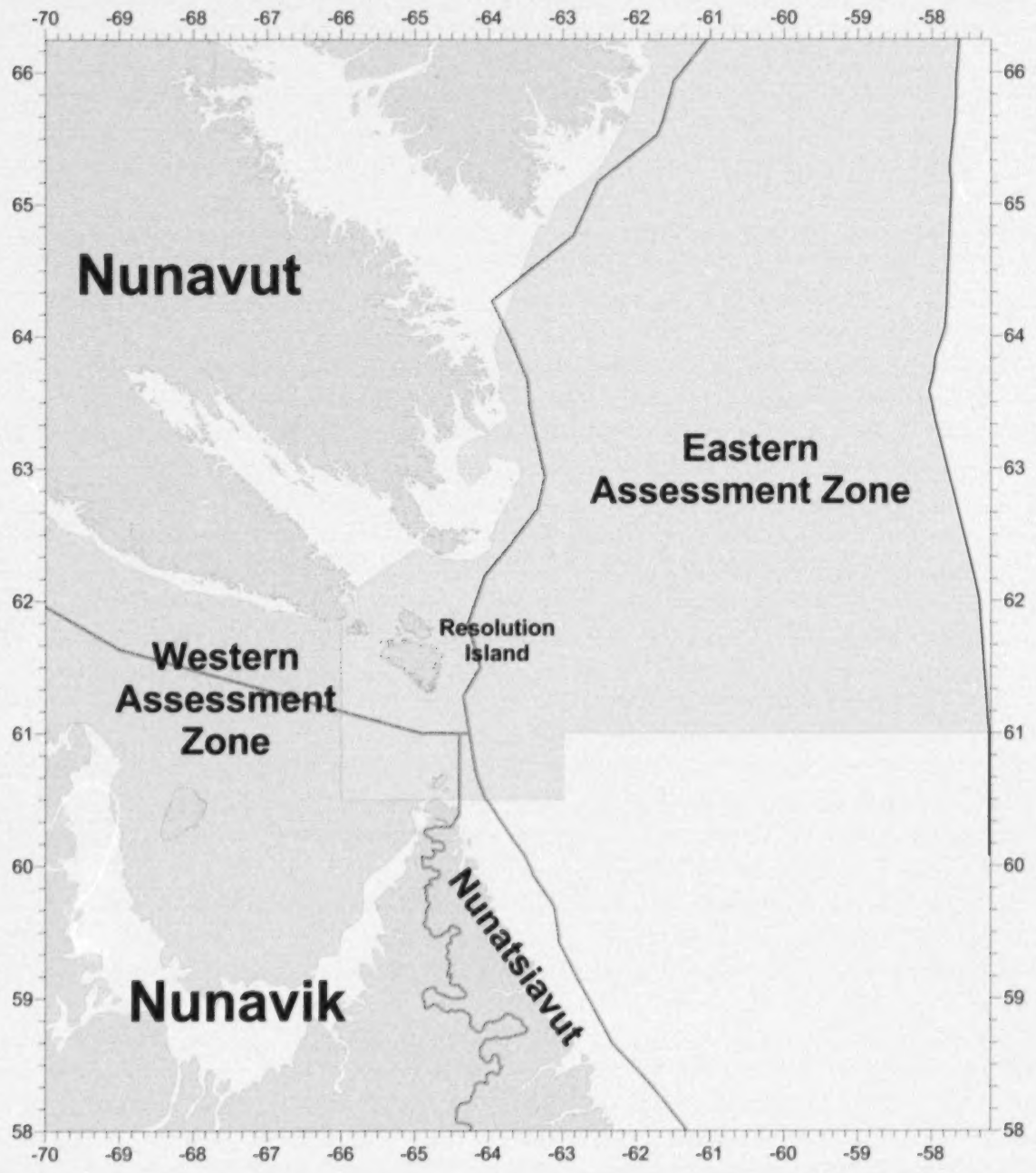

Figure 2. The Eastern (blue) and Western (green) Assessment Zones. Red line shows the borders of the Nunavut, Nunatsiavut and Nunavik Land Claims Areas.

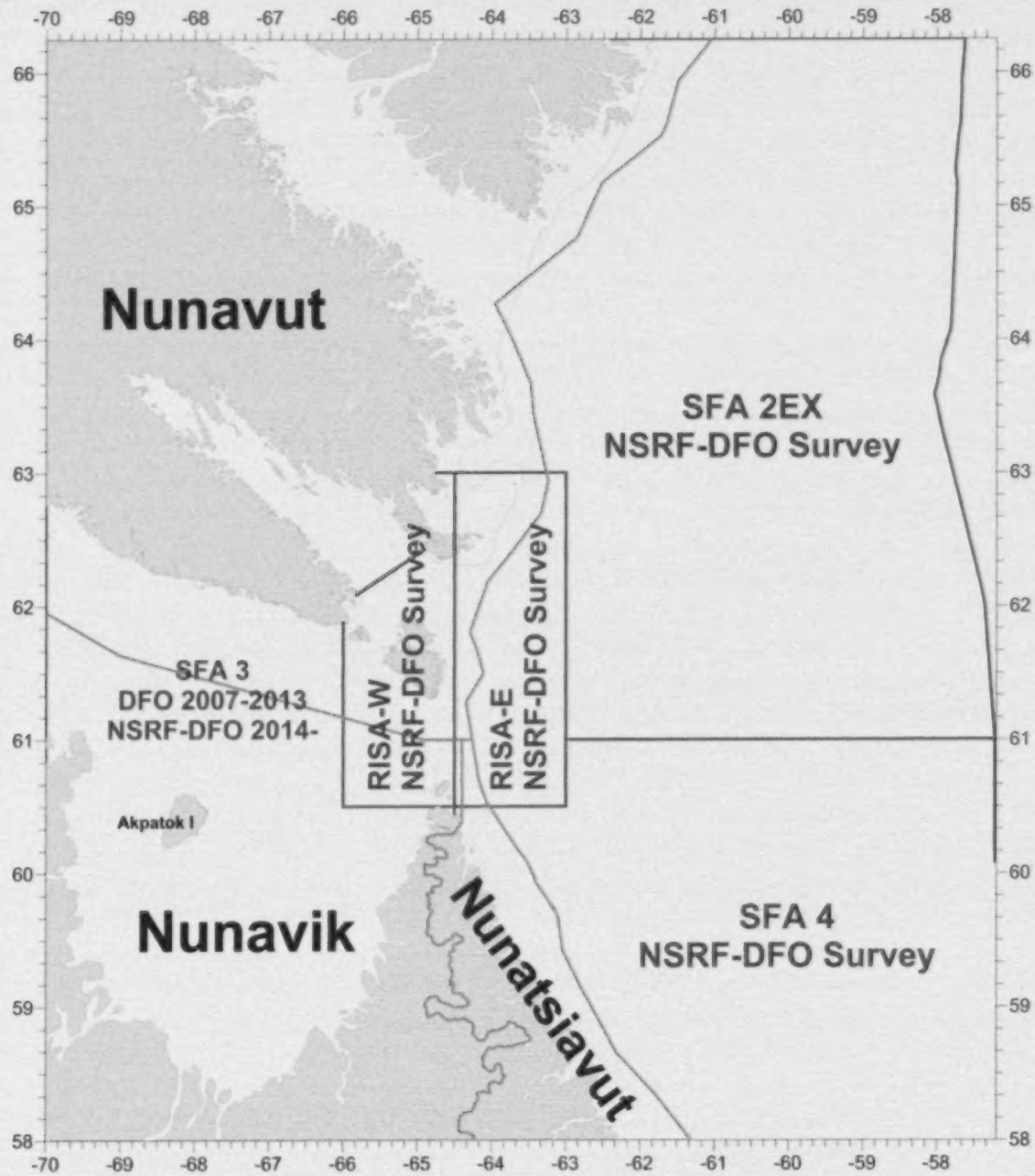

Figure 3. Location of the northern survey areas within the Eastern and Western Assessment Zones, Shrimp Fishing Area (SFA) 2 Exploratory (EX), Resolution Island Study Area (RISA)–East (E), RISA–West (W) and SFA 3, used in the assessment of domestic Canadian Pandalid Stocks by the Central and Arctic Region. SFA 4 is assessed by Newfoundland and Labrador Region. Red line shows the borders of the Nunavut, Nunatsiavut and Nunavik Land Claim Areas.

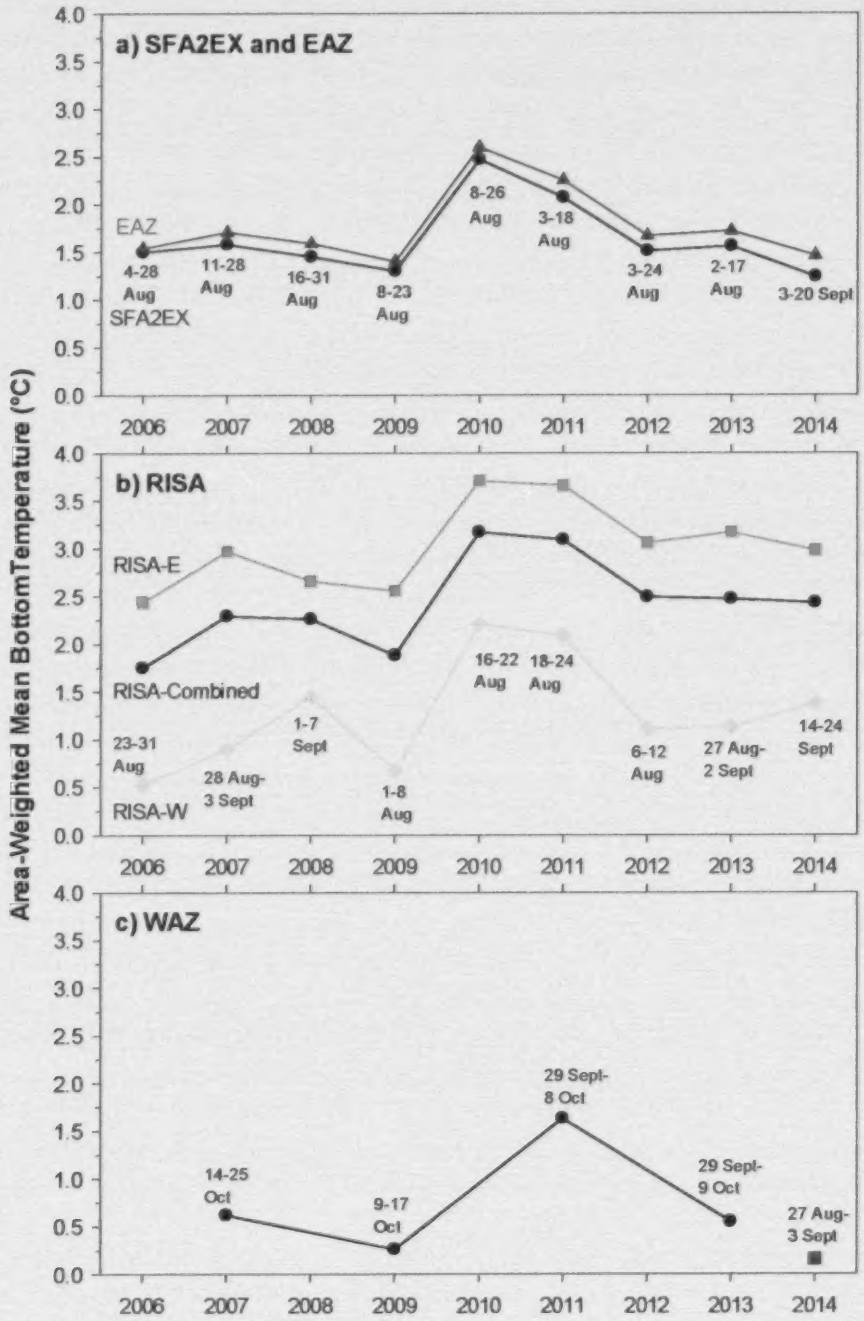

Figure 4. Mean area-weighted bottom temperatures in the Eastern Assessment Zone for a) SFA2EX (black circle) and EAZ (blue triangle), and b) RISA showing RISA combined (black circle), RISA-E (red square) and RISA-W (green diamond), and c) the Western Assessment Zone for the 2006-2014 surveys. Point label indicate the dates over which samples were taken.

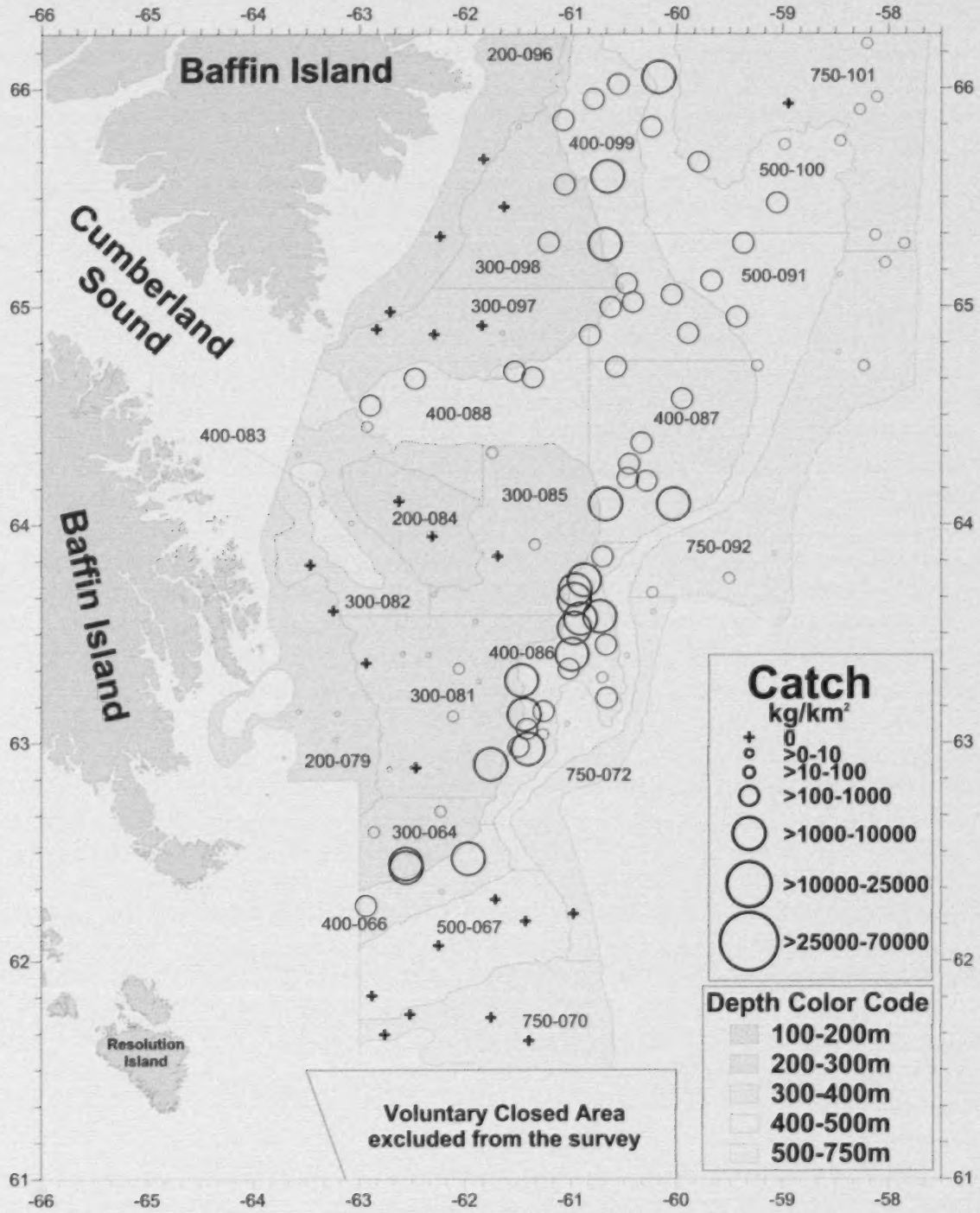

Figure 5. Standardized Pandalus borealis *catch from the 2013 SFA2EX survey area overlying the depth contours and strata of the survey area.*

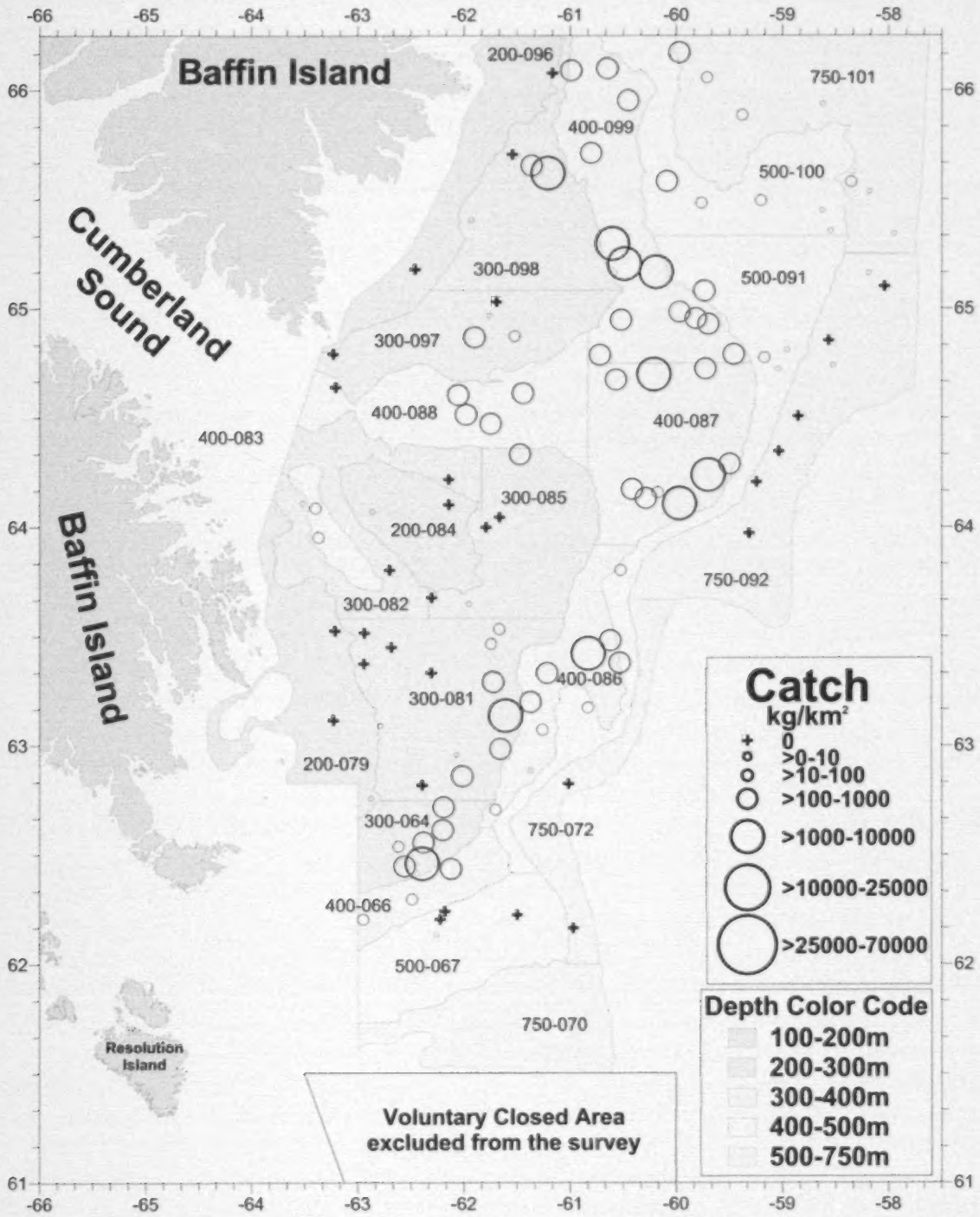

Figure 6. Standardized Pandalus borealis *catch from the 2014 SFA2EX survey area overlying the depth contours and strata of the survey area.*

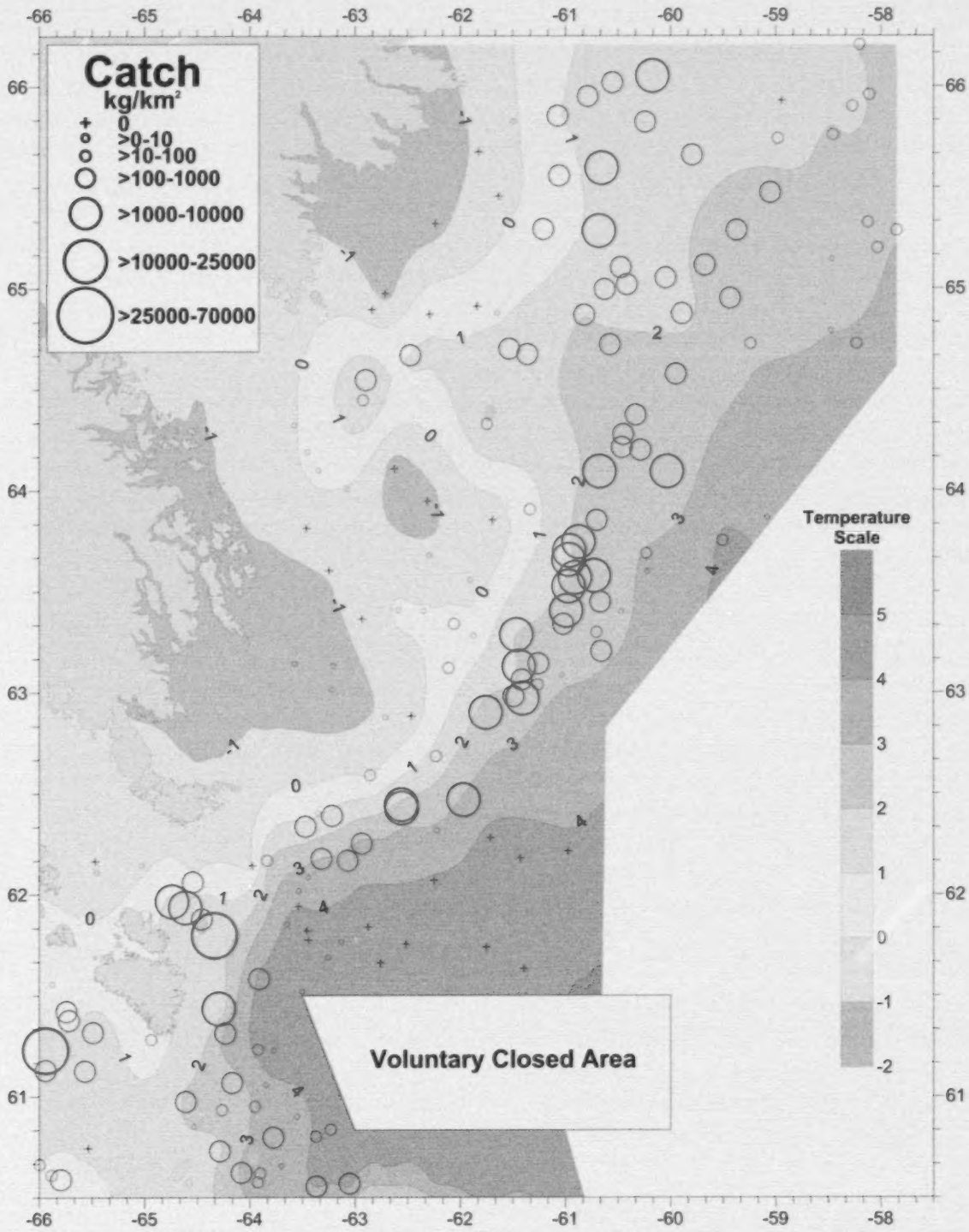

Figure 7. 2013 standardized Pandalus borealis *catch from the Eastern Assessment Zone (SFA2EX and RISA) overlying the mean bottom temperature contours observed in the survey areas.*

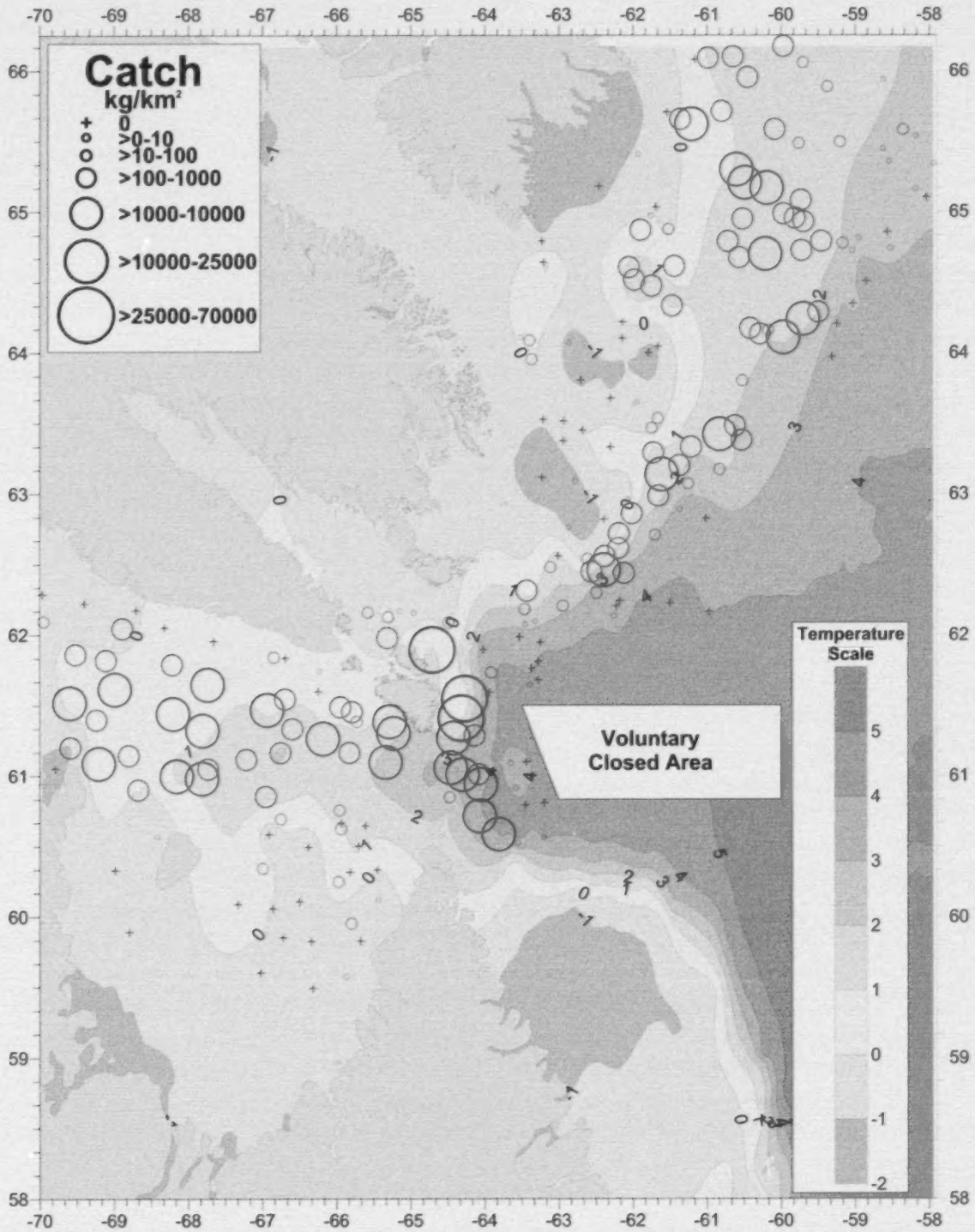

Figure 8. 2014 standardized Pandalus borealis *catch from the Eastern and Western Assessment Zones overlying mean bottom temperature contours observed in the survey areas.*

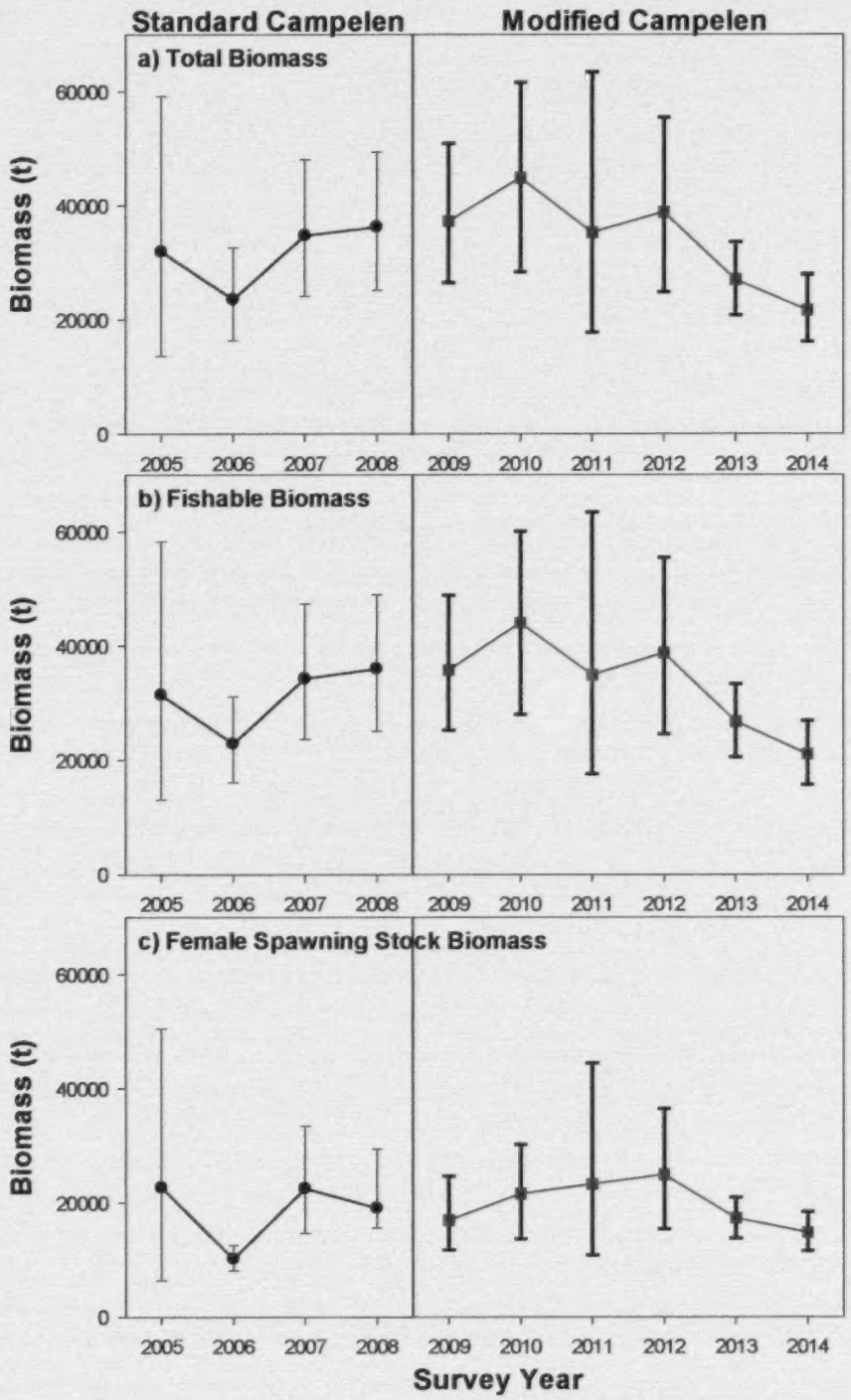

Figure 9. Fishable and female spawning stock biomass indices of Pandalus borealis *in the SFA2EX survey area for the years 2005-2014. Note the change to the modified Campelen trawl.*

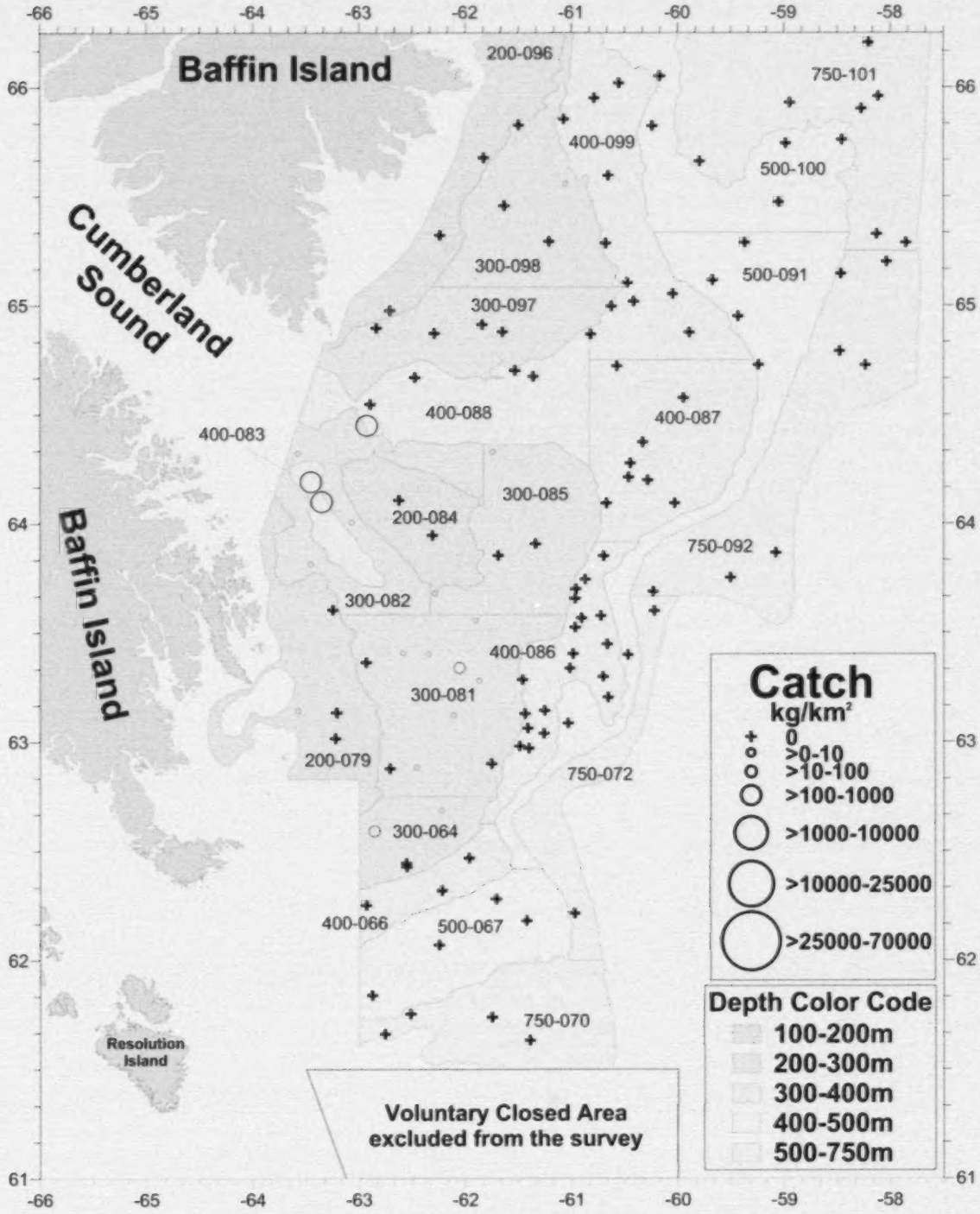

Figure 10. Standardized Pandalus montagui *catch from the SFA2EX survey area in 2013 overlying the depth contours and strata of the survey area.*

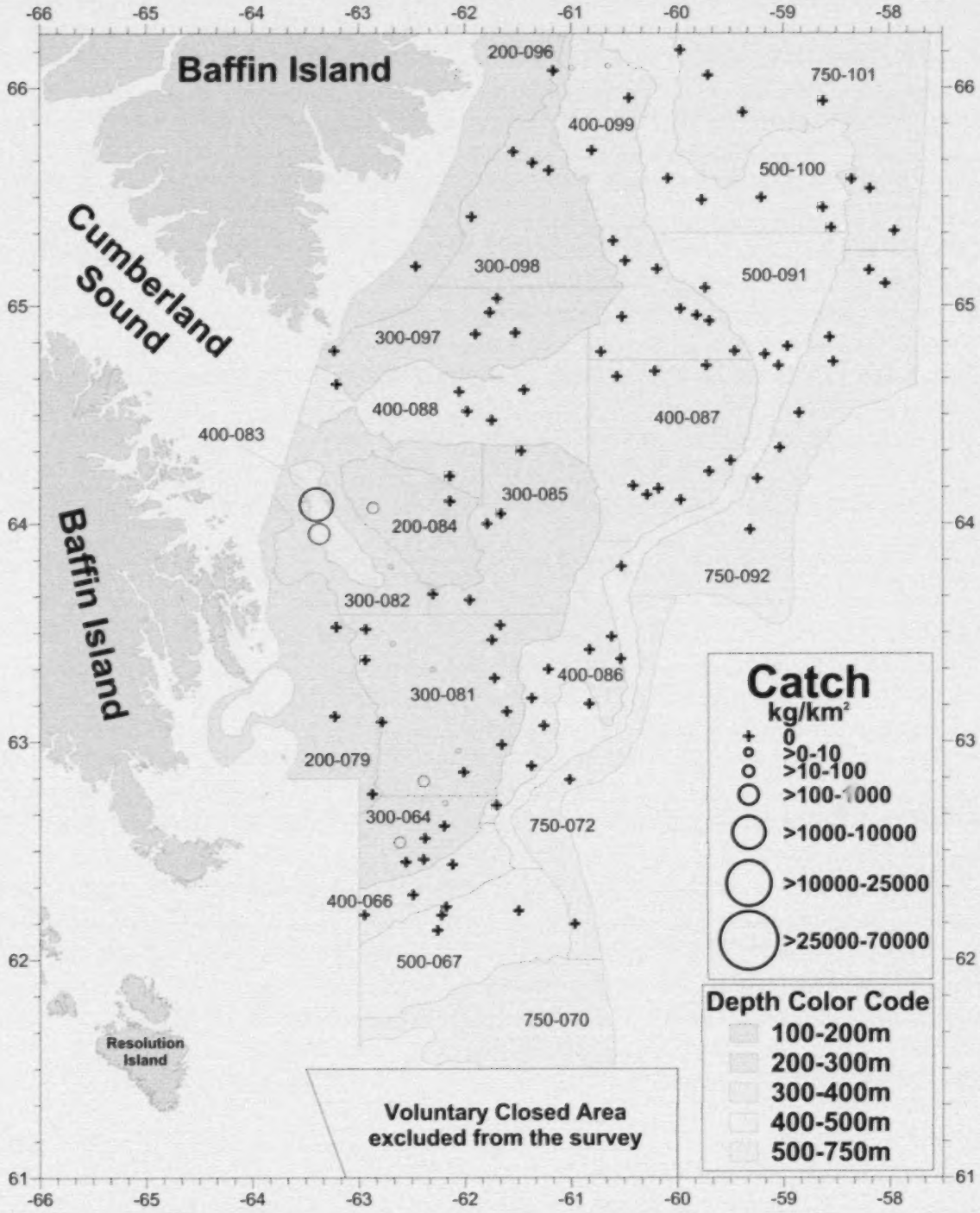

Figure 11. Standardized Pandalus montagui *catch from the SFA2EX survey area in 2014 overlying the depth contours and strata of the survey area.*

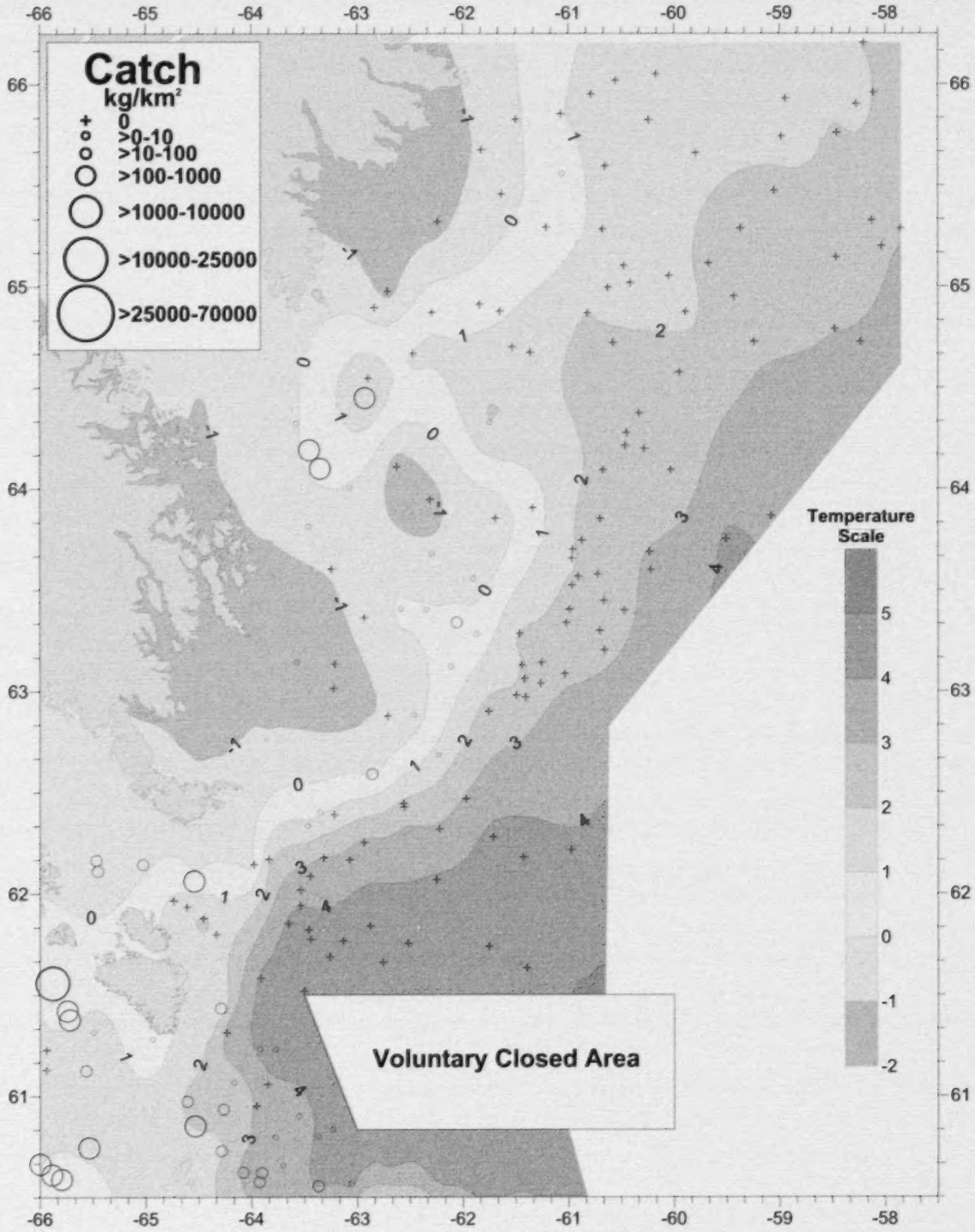

Figure 12. 2013 standardized Pandalus montagui *catch in the Eastern Assessment Zone survey overlying the temperature contours observed in the survey areas.*

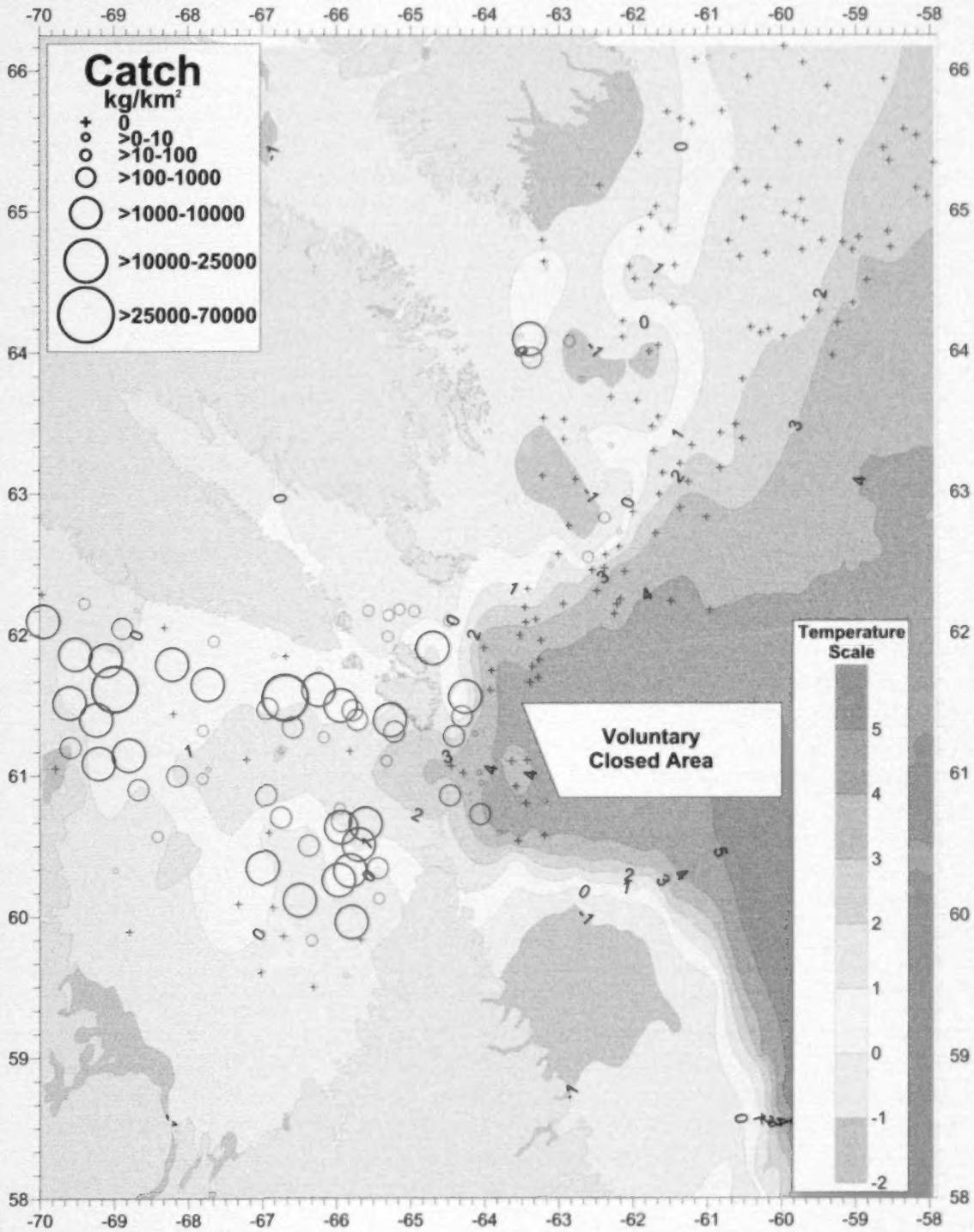

Figure 13. 2014 standardized Pandalus montagui *catch in the Eastern and Western Assessment Zones survey overlying the temperature contours observed in the survey areas.*

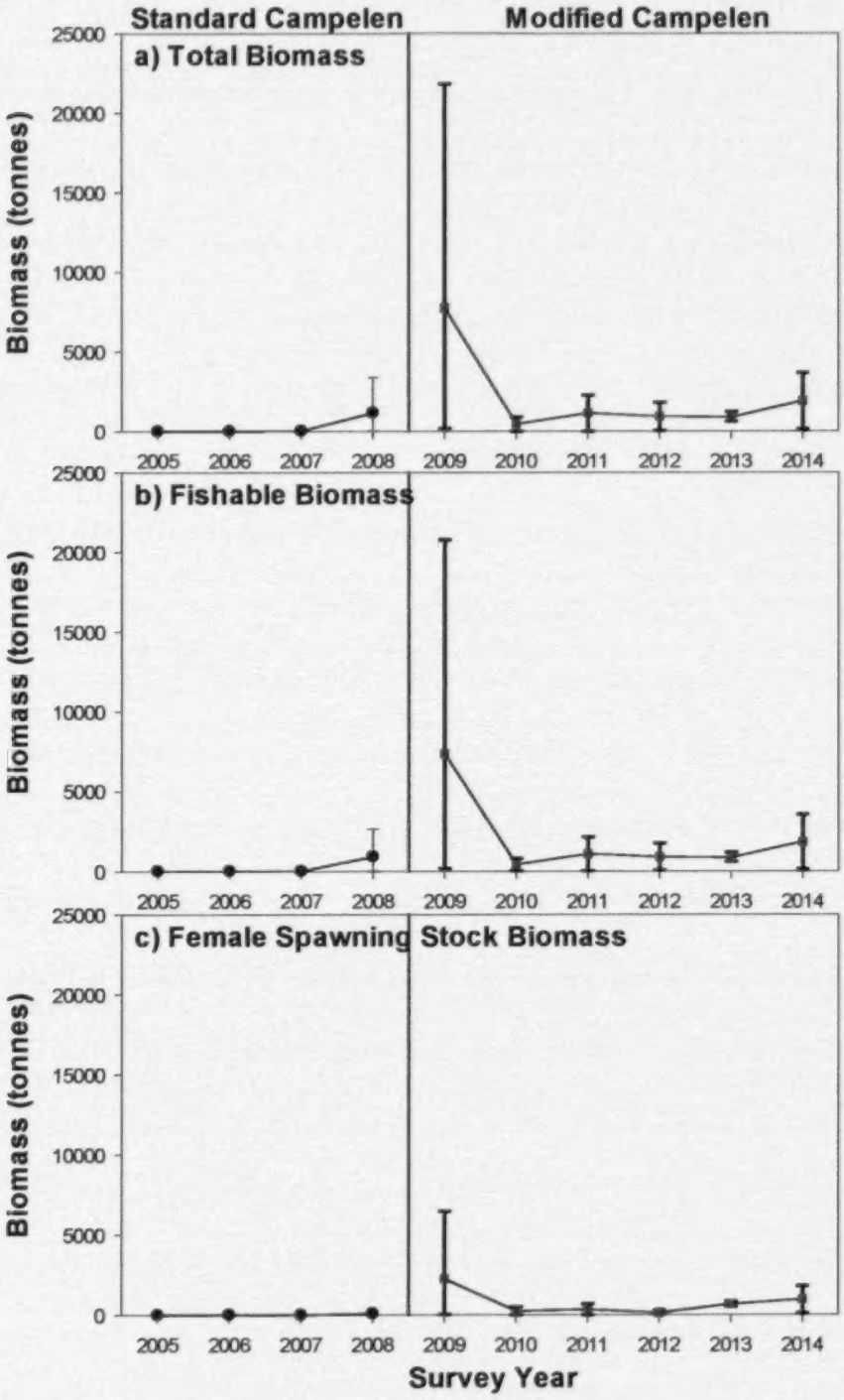

Figure 14. Total, fishable and female spawning stock biomass indices of Pandalus montagui *in the SFA2EX survey area for the years 2005-2014. Note the change to the modified Campelen trawl.*

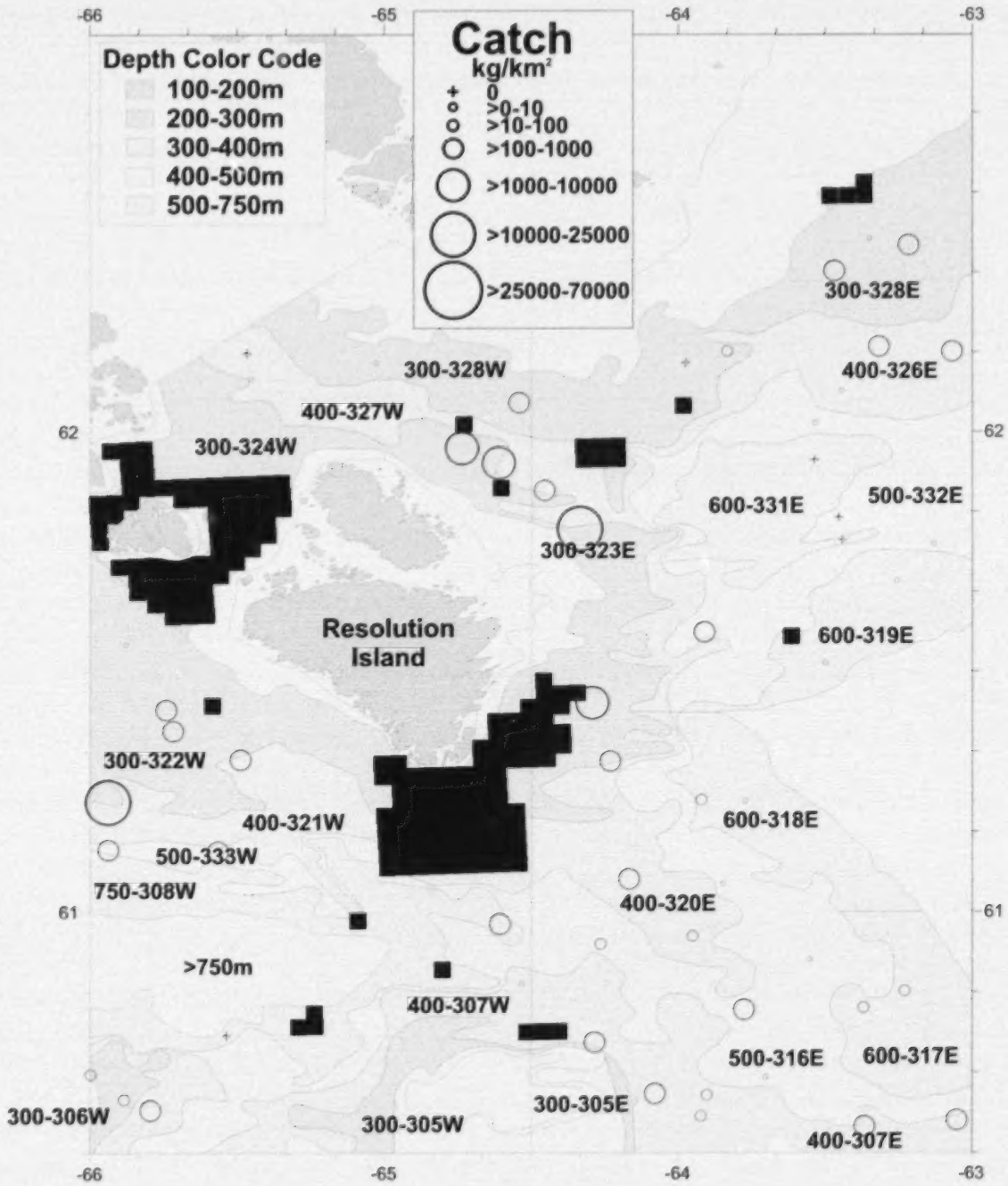

Figure 15. Standardized Pandalus borealis *catch from the 2013 RISA survey areas overlying the depth contours and strata of the survey area. Blackened areas are cells removed from the survey design because of untrawlable bottom.*

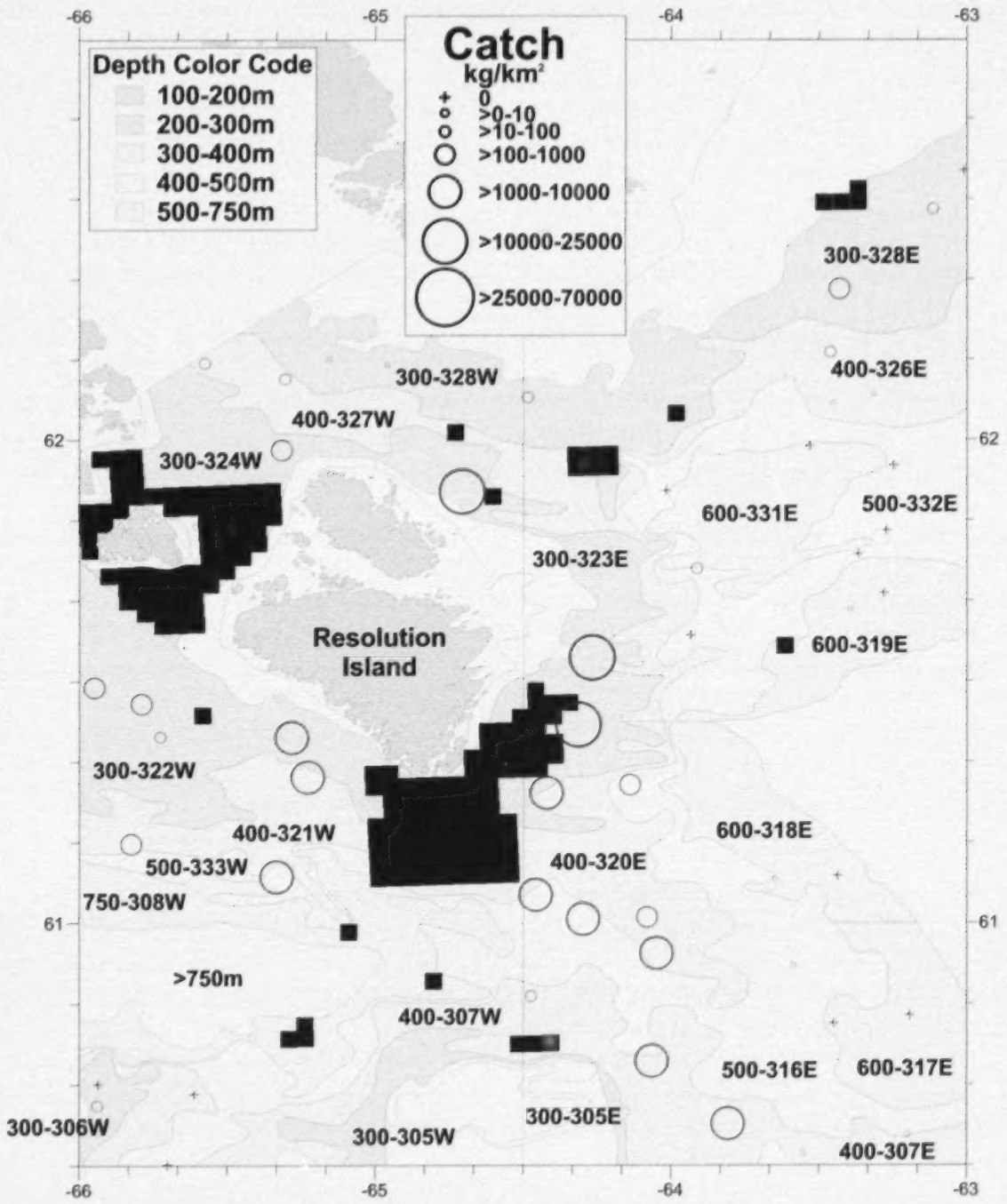

Figure 16. Standardized Pandalus borealis *catch from the 2014 RISA survey areas overlying the depth contours and strata of the survey area. Blackened areas are cells removed from the survey design because of untrawlable bottom.*

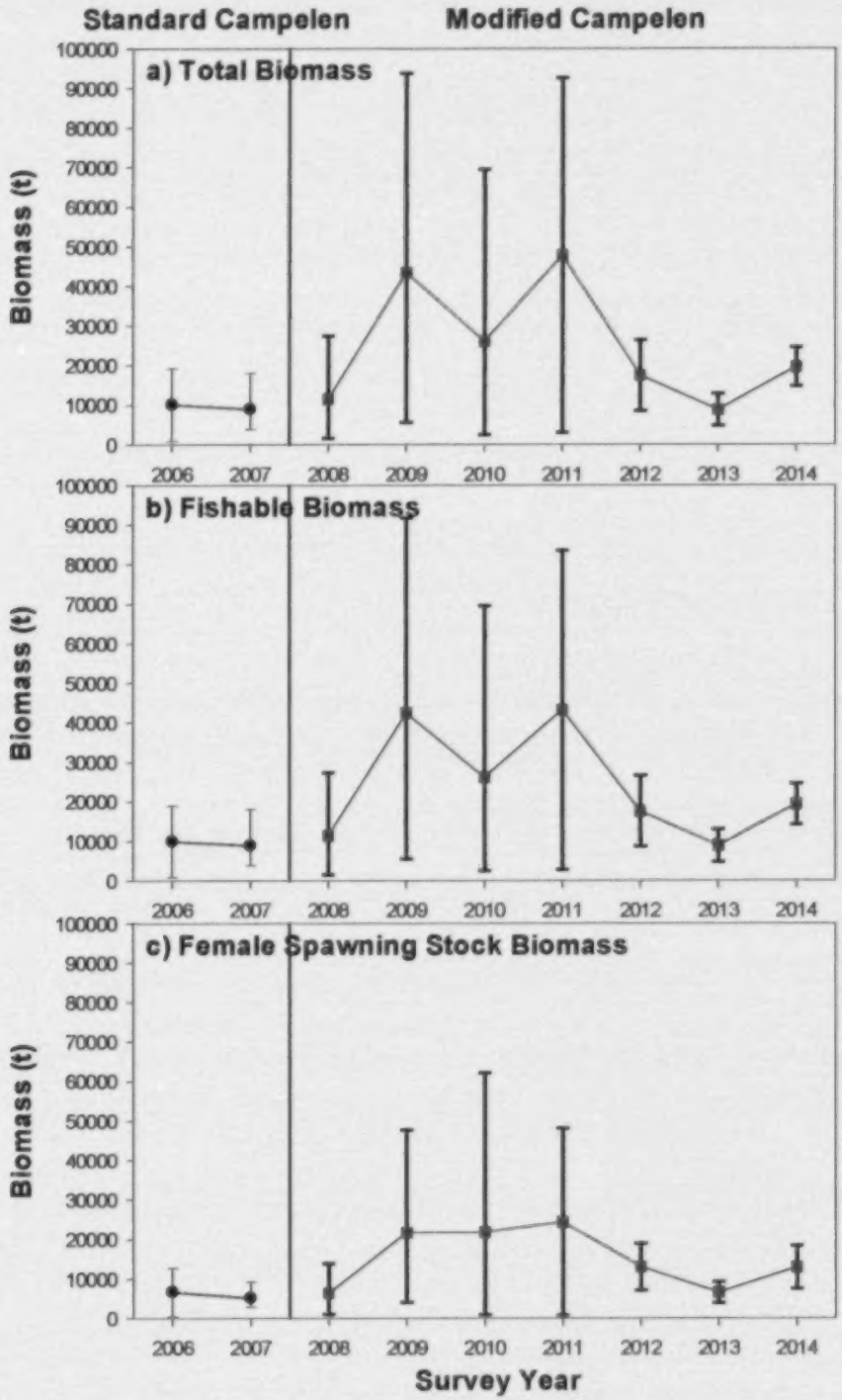

Figure 17. Total, fishable and female spawning stock biomass indices of Pandalus borealis *in the RISA-East survey area for the years 2006-2014. Note the change to the modified Campelen trawl.*

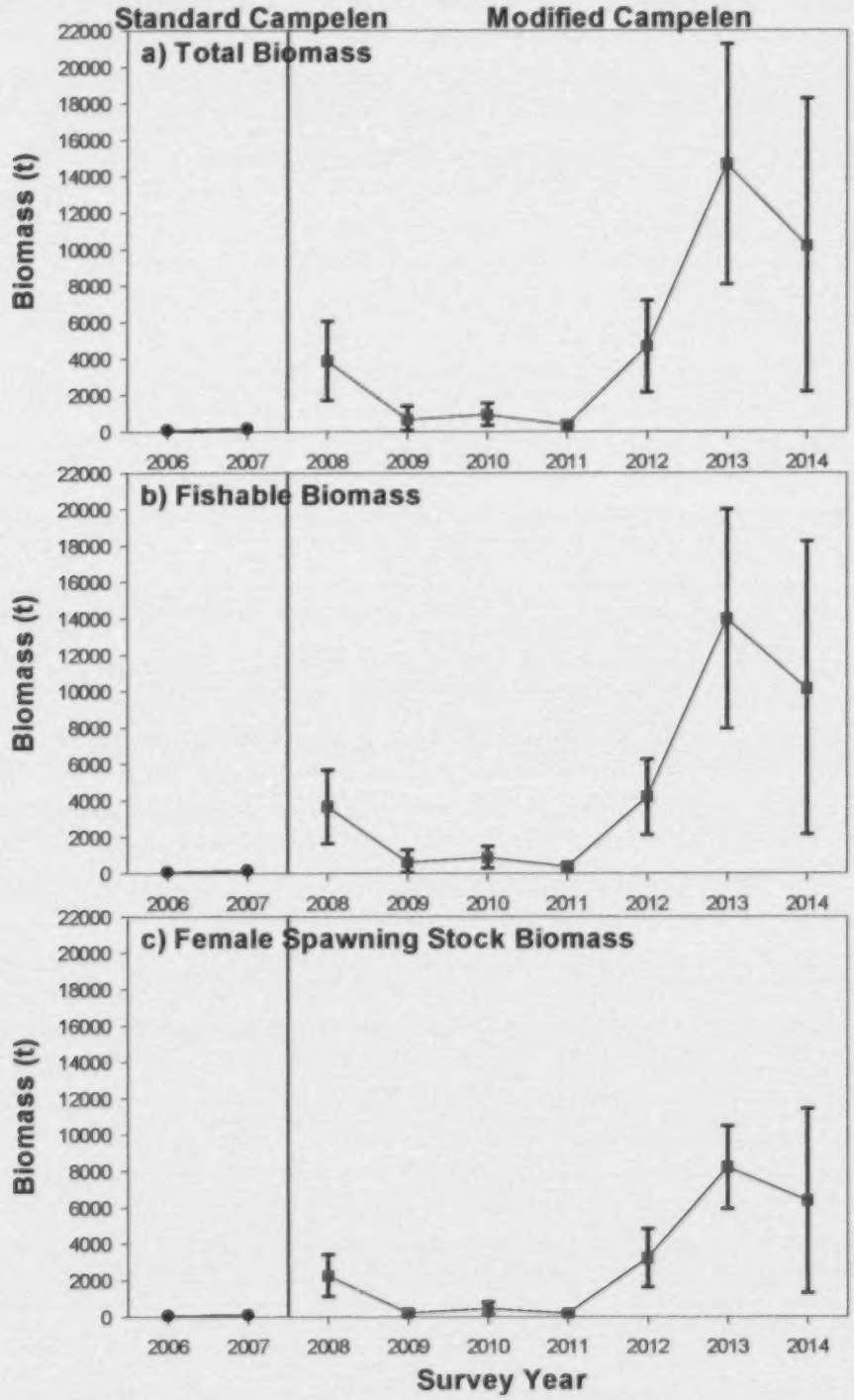

Figure 18. Total, fishable and female spawning stock biomass indices of Pandalus borealis *in the RISA-West survey area for the years 2006-2014. Note the change to the modified Campelen trawl.*

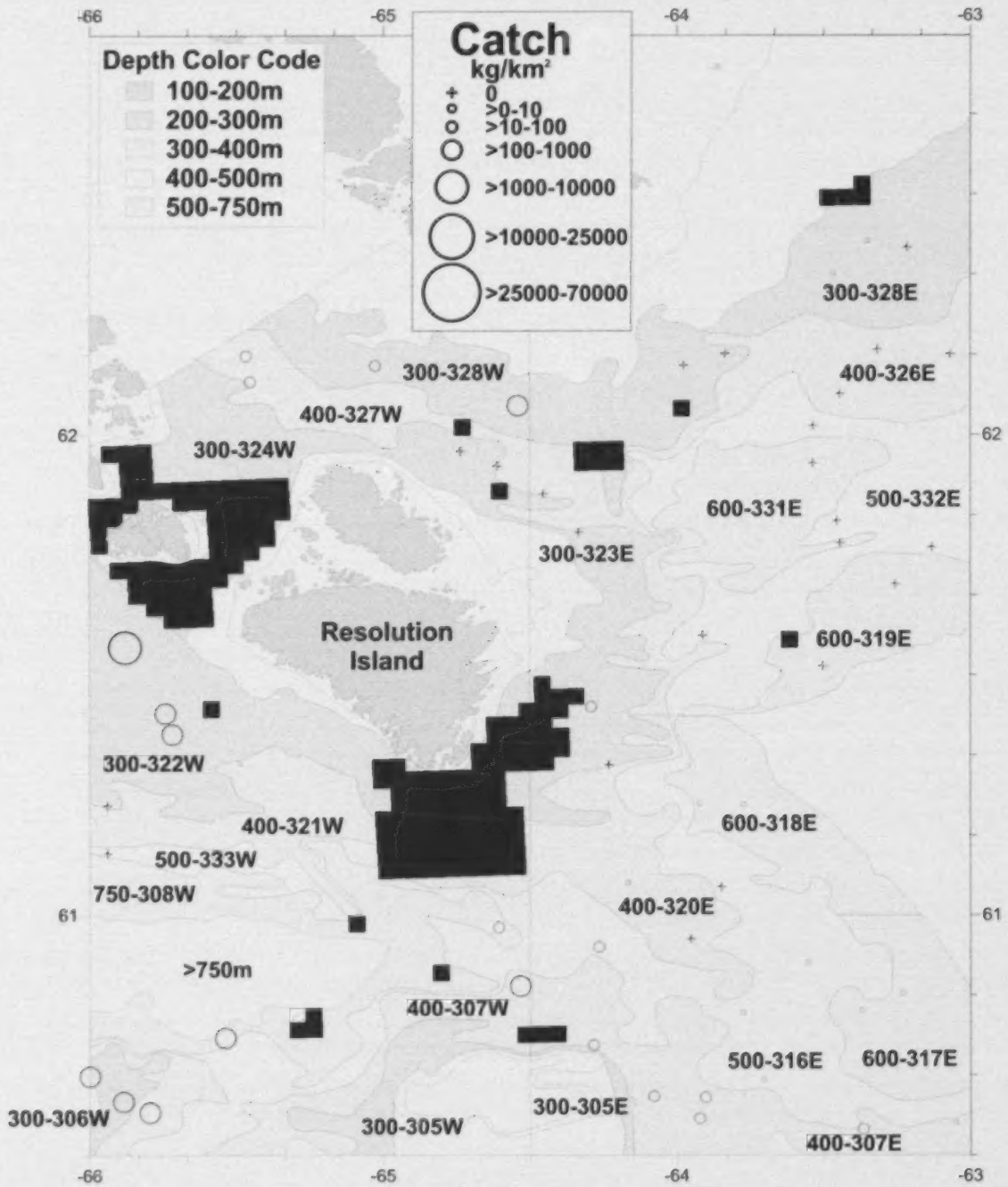

Figure 19. Standardized Pandalus montagui *catch from the RISA survey areas in 2013 overlying the depth contours and strata of the survey area. Blackened areas are cells removed from the survey design because of untrawlable bottom.*

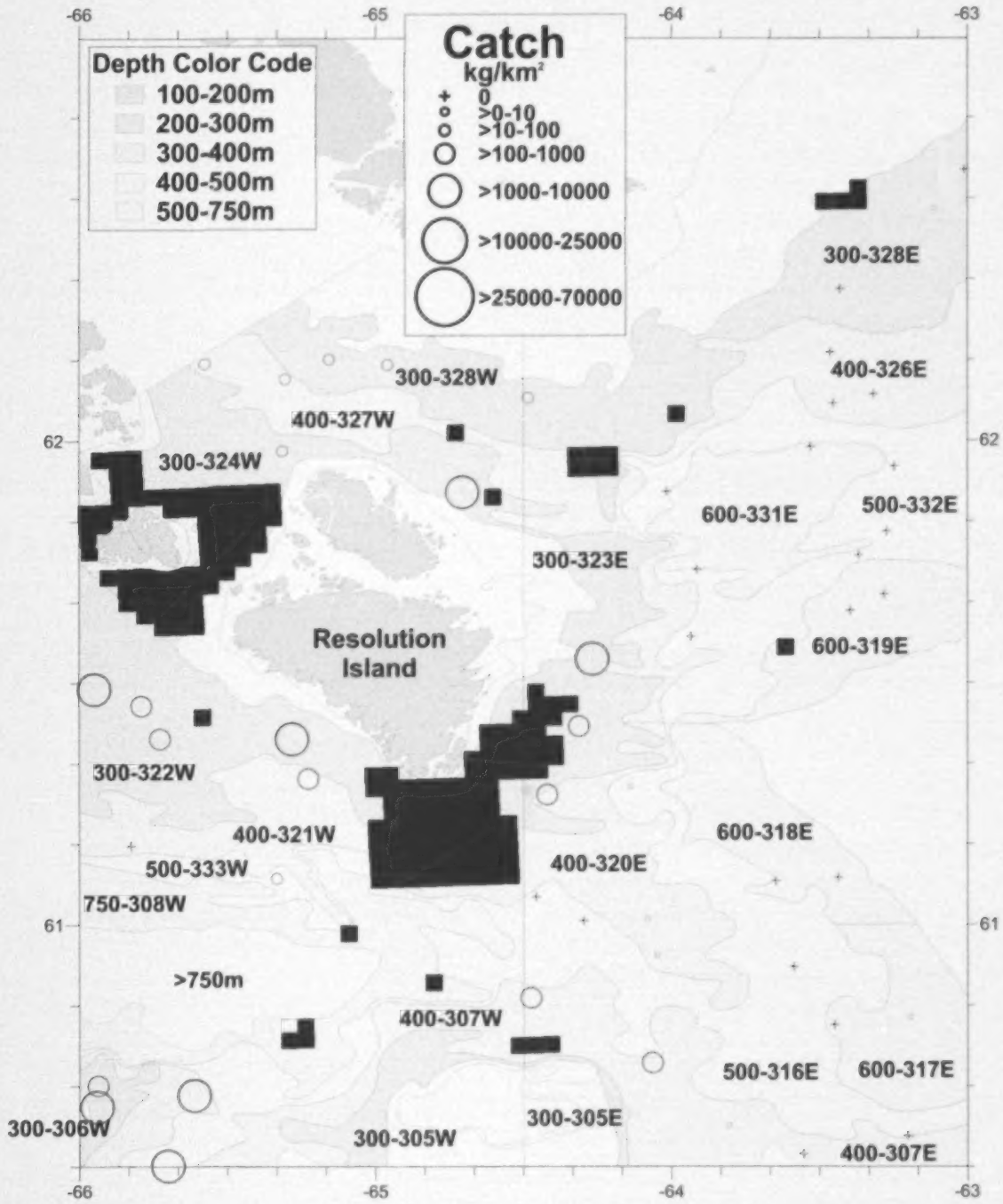

Figure 20. Standardized Pandalus montagui *catch from the RISA survey areas in 2014 overlying the depth contours and strata of the survey area. Blackened areas are cells removed from the survey design because of untrawlable bottom.*

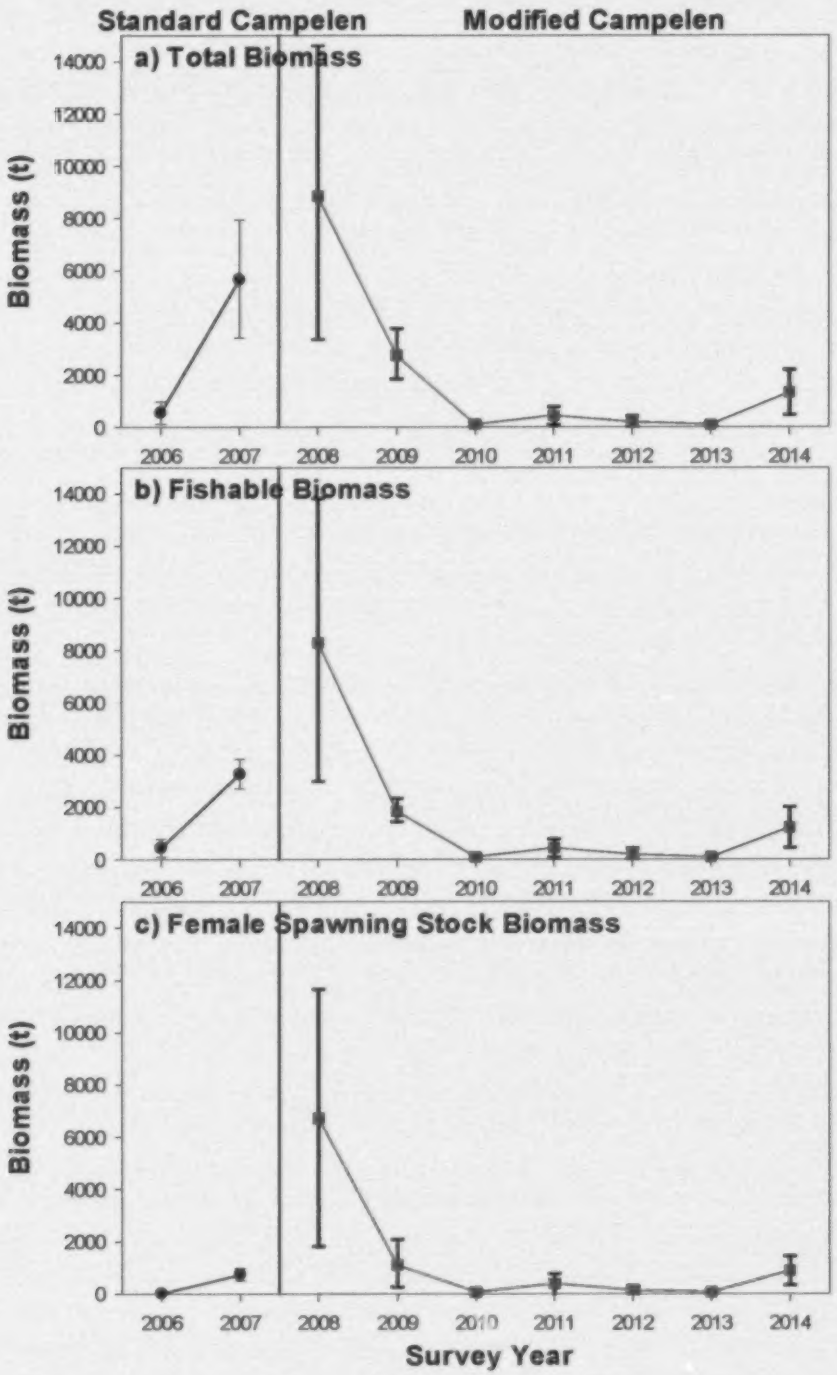

Figure 21. Total, fishable and female spawning stock biomass indices of Pandalus montagui *in the RISA-East survey areas for the years 2006-2014. Note the change to the modified Campelen trawl.*

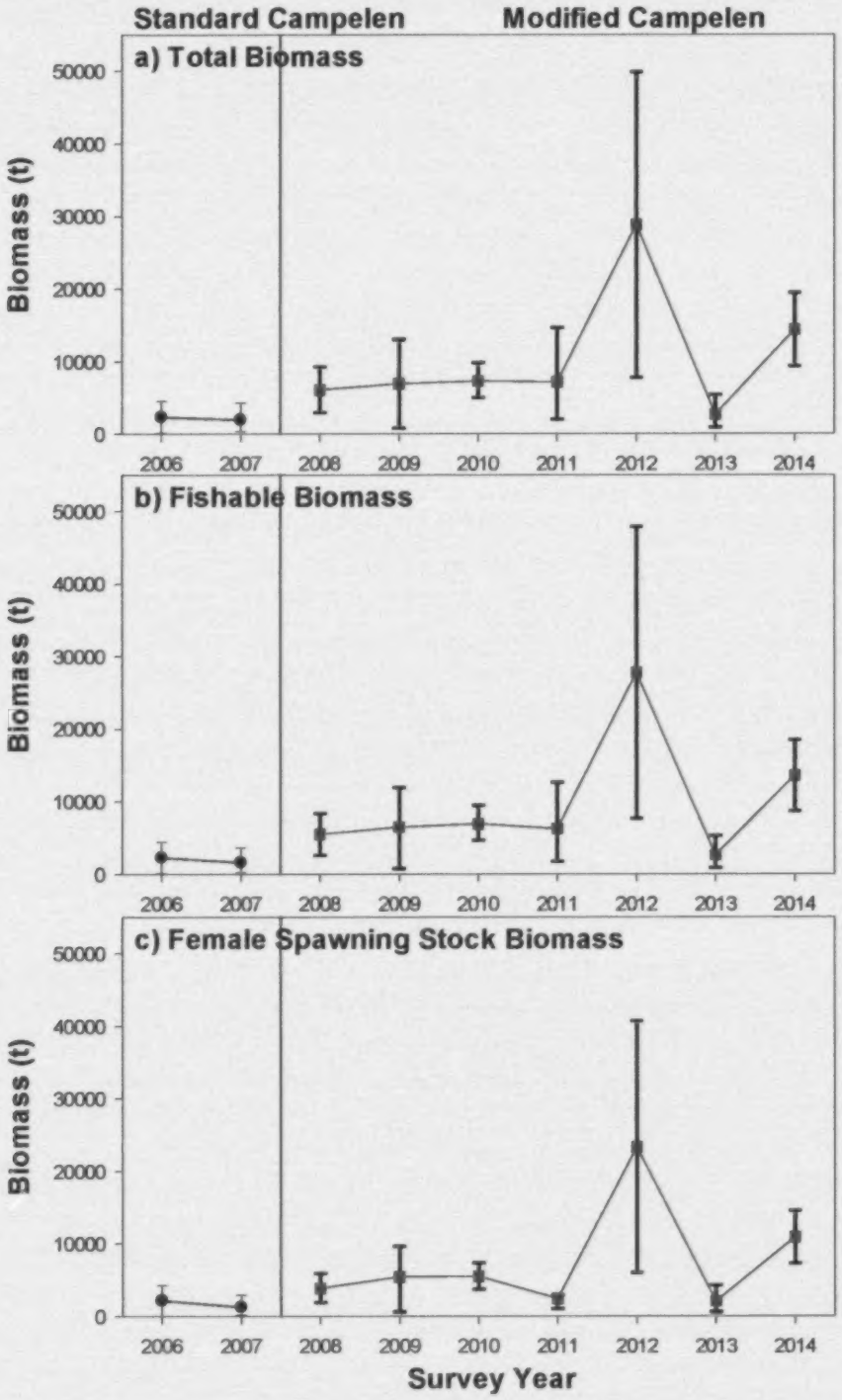

Figure 22. Total, fishable and female spawning stock biomass indices of Pandalus montagui *in the RISA-West survey areas for the years 2006-2014. Note the change to the modified Campelen trawl.*

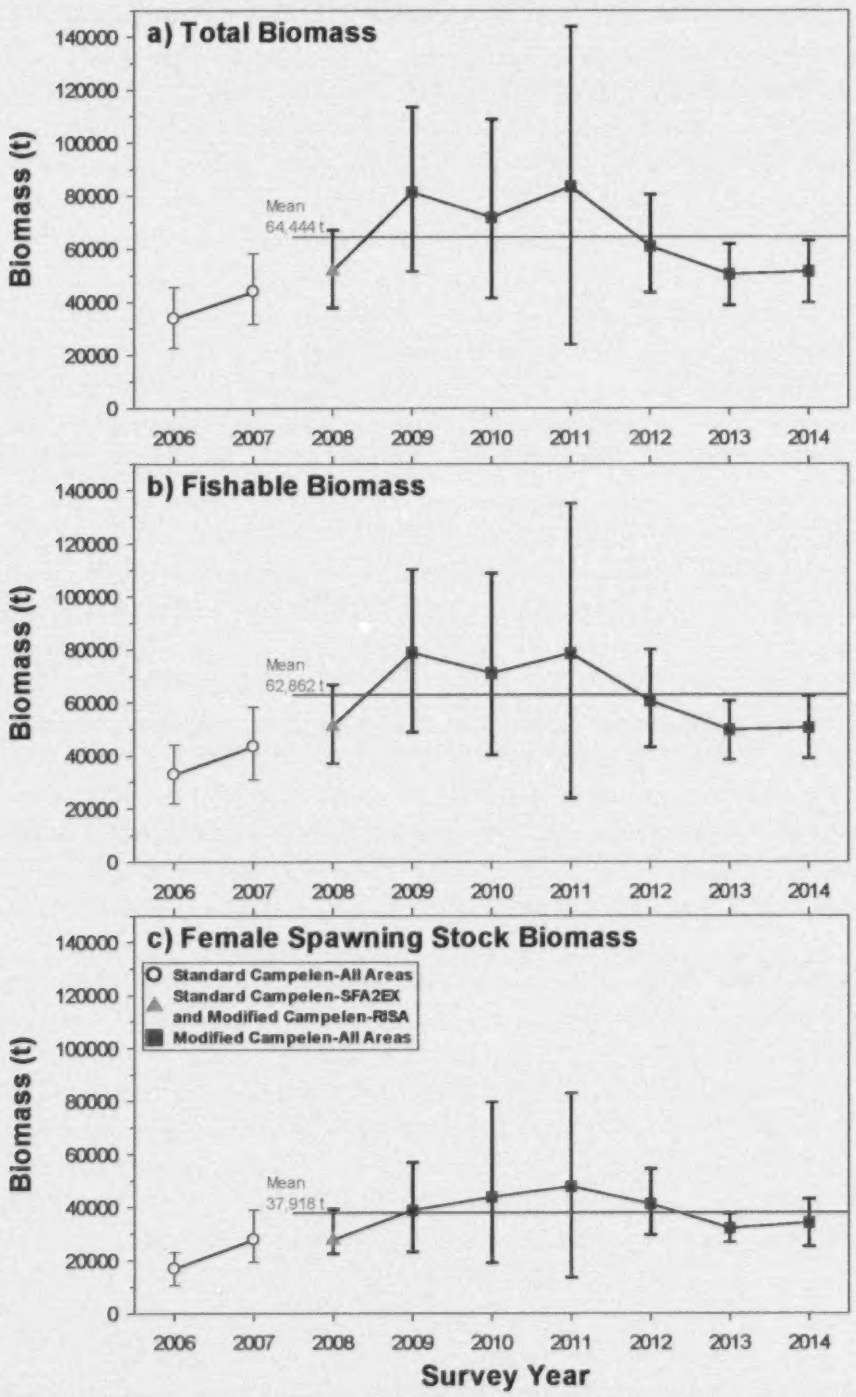

Figure 23. The Eastern Assessment Zone total, fishable and female spawning stock biomass indices of Pandalus borealis *for the survey years 2006–2014. The first two years of survey data (2006–2007) are not considered to be comparable with the rest of the series because of poor trawl performance around Resolution Island. Error bars are 95% confidence ranges.*

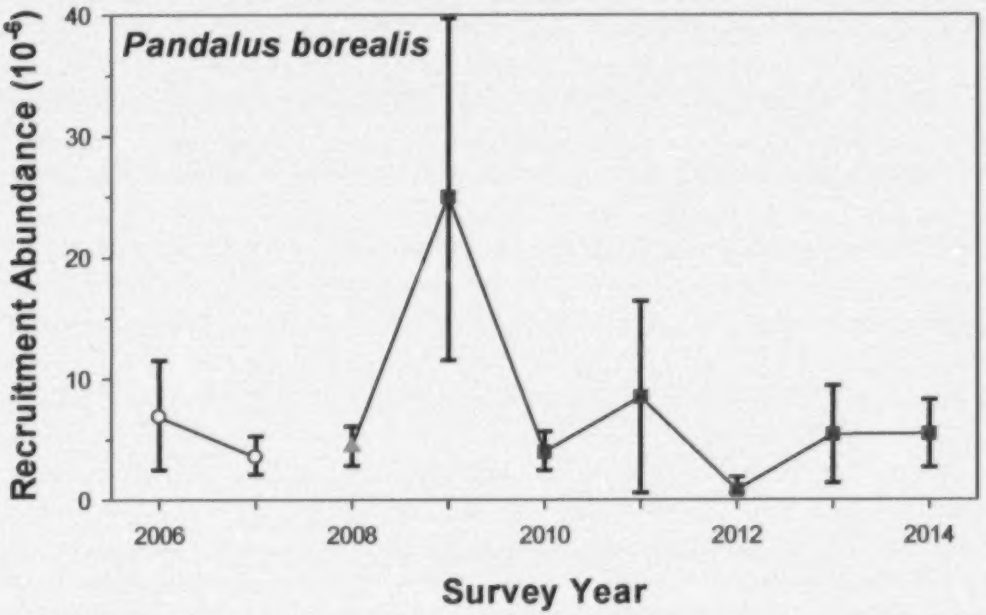

Figure 24. Recruitment index based on the Campelen cod end collection of 11.5-17.0 mm carapace length Pandalus borealis *in the Eastern Assessment Zone for the survey years 2006-2014.*

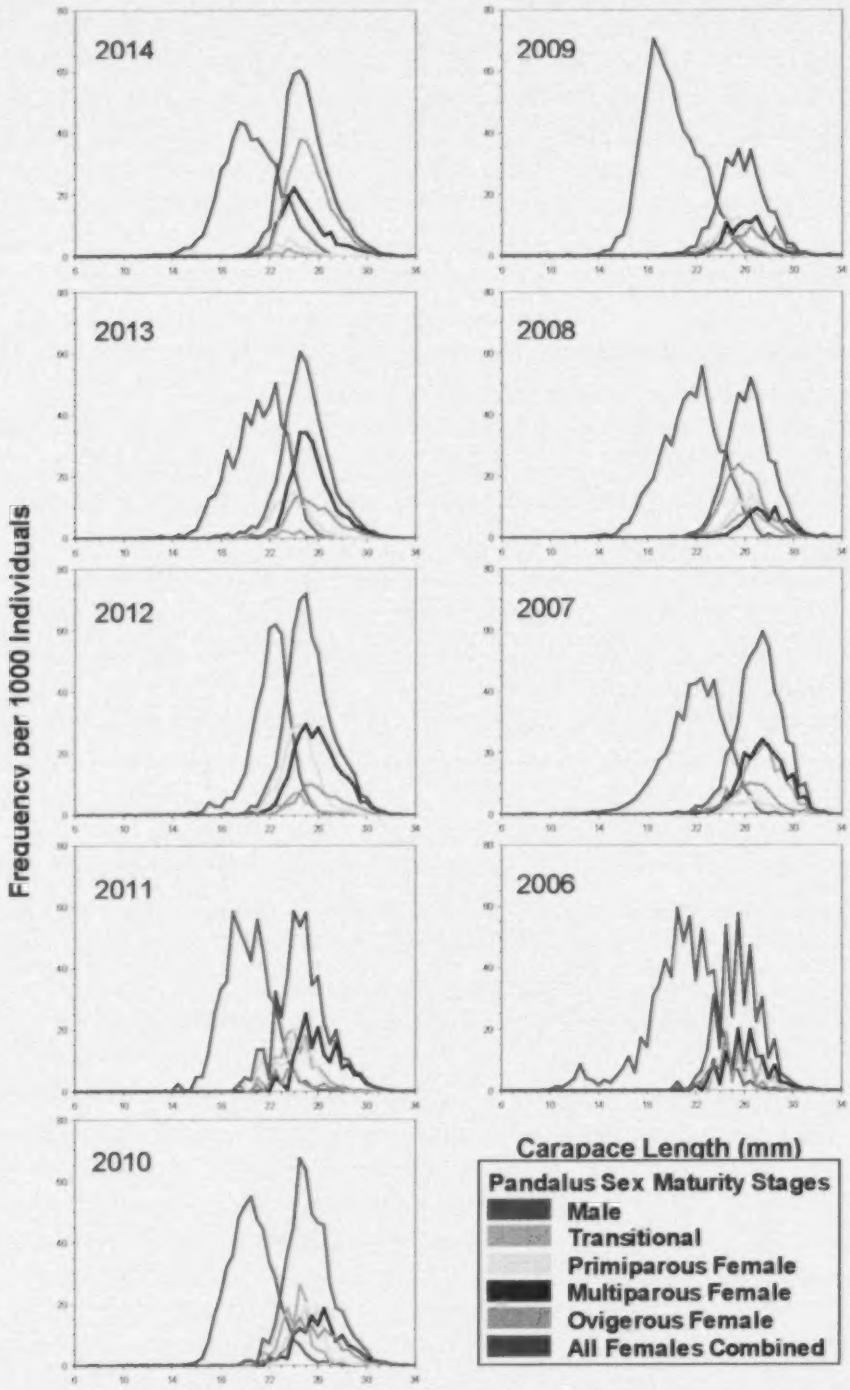

Figure 25. Length frequency curves for all sex maturities of Pandalus borealis *collected in the Campelen cod end in the Eastern Assessment Zone over the survey years 2006-2014.*

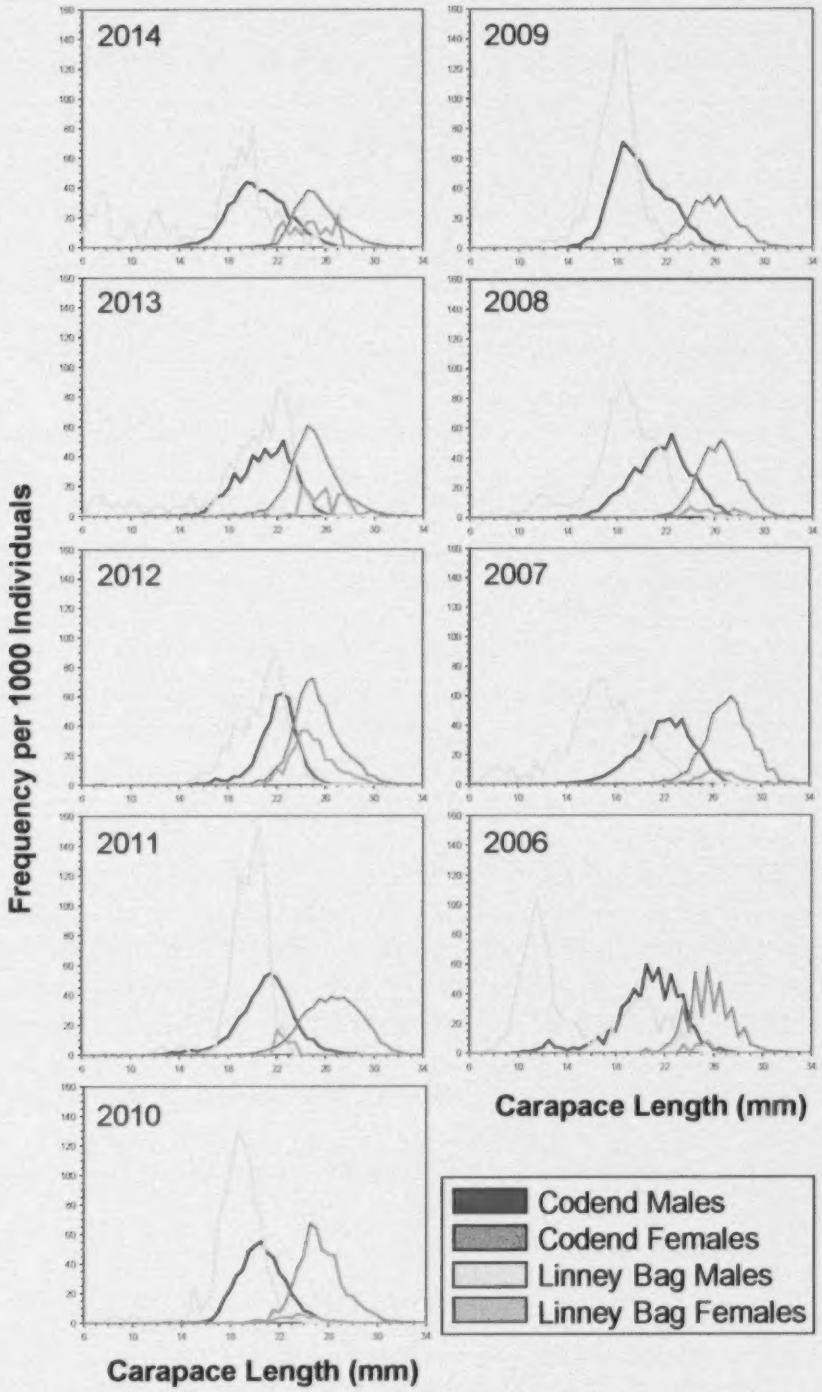

Figure 26. Overall length frequency distributions of male and female Pandalus borealis *in the Eastern Assessment Zone as captured in the cod end (CE) and Linney Bag (LB).*

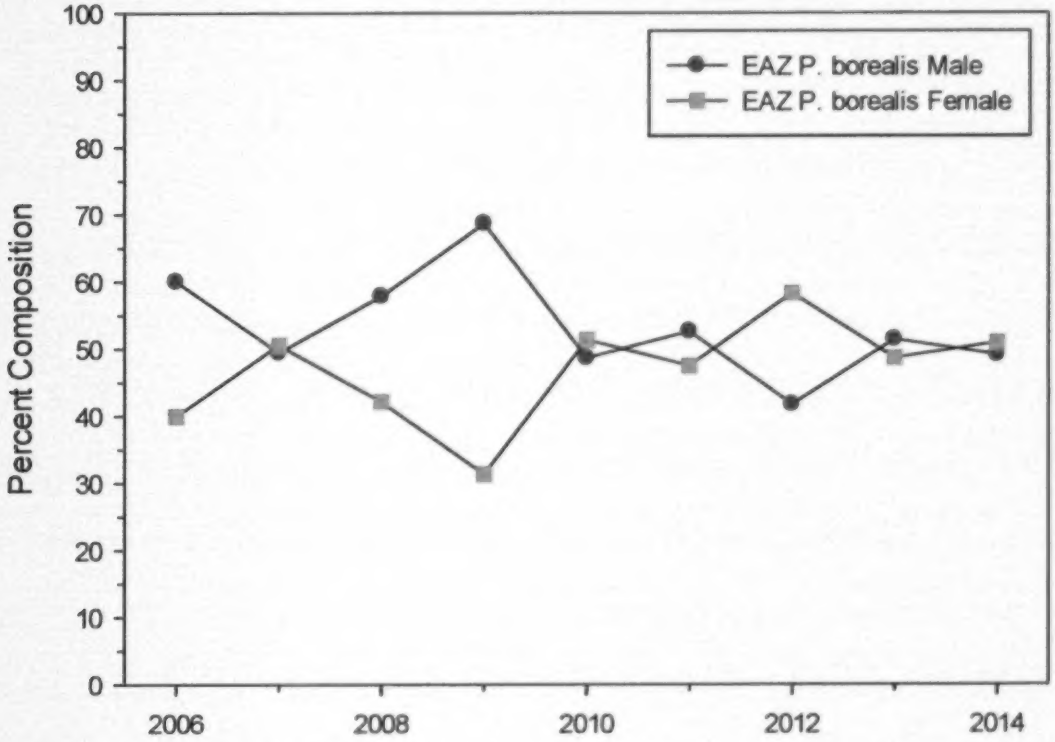

Figure 27. Percent sex composition of Pandalus borealis *in the Eastern Assessment Zone for 2006-2014.*

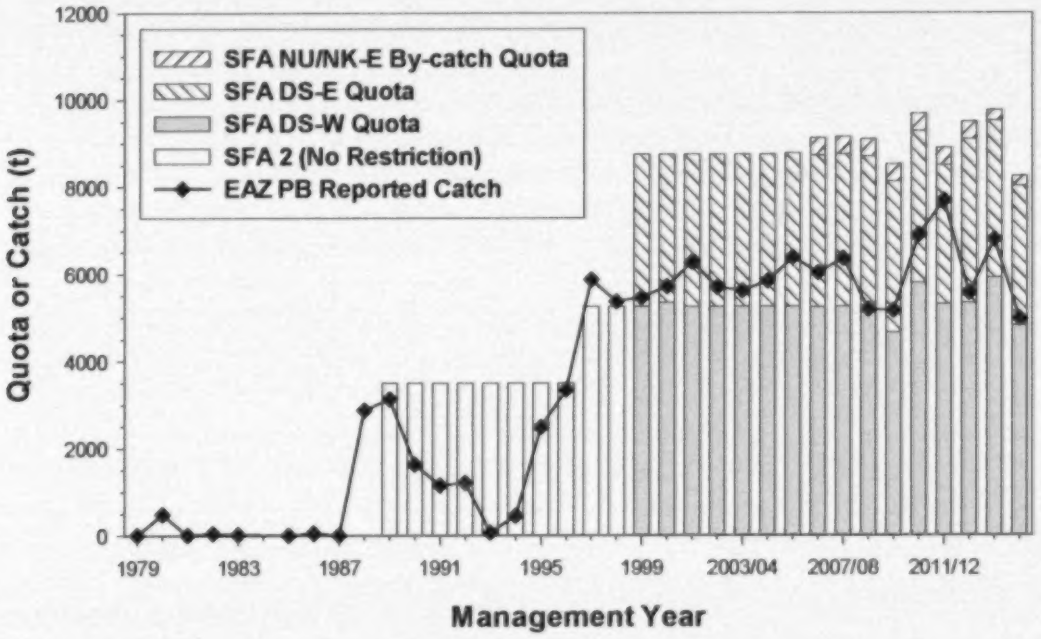

Figure 28. Eastern Assessment Zone Pandalus borealis *TAC and catch reported in the Canadian Atlantic Quota Report. The 2014/15 data are as of 22 January 2015.*

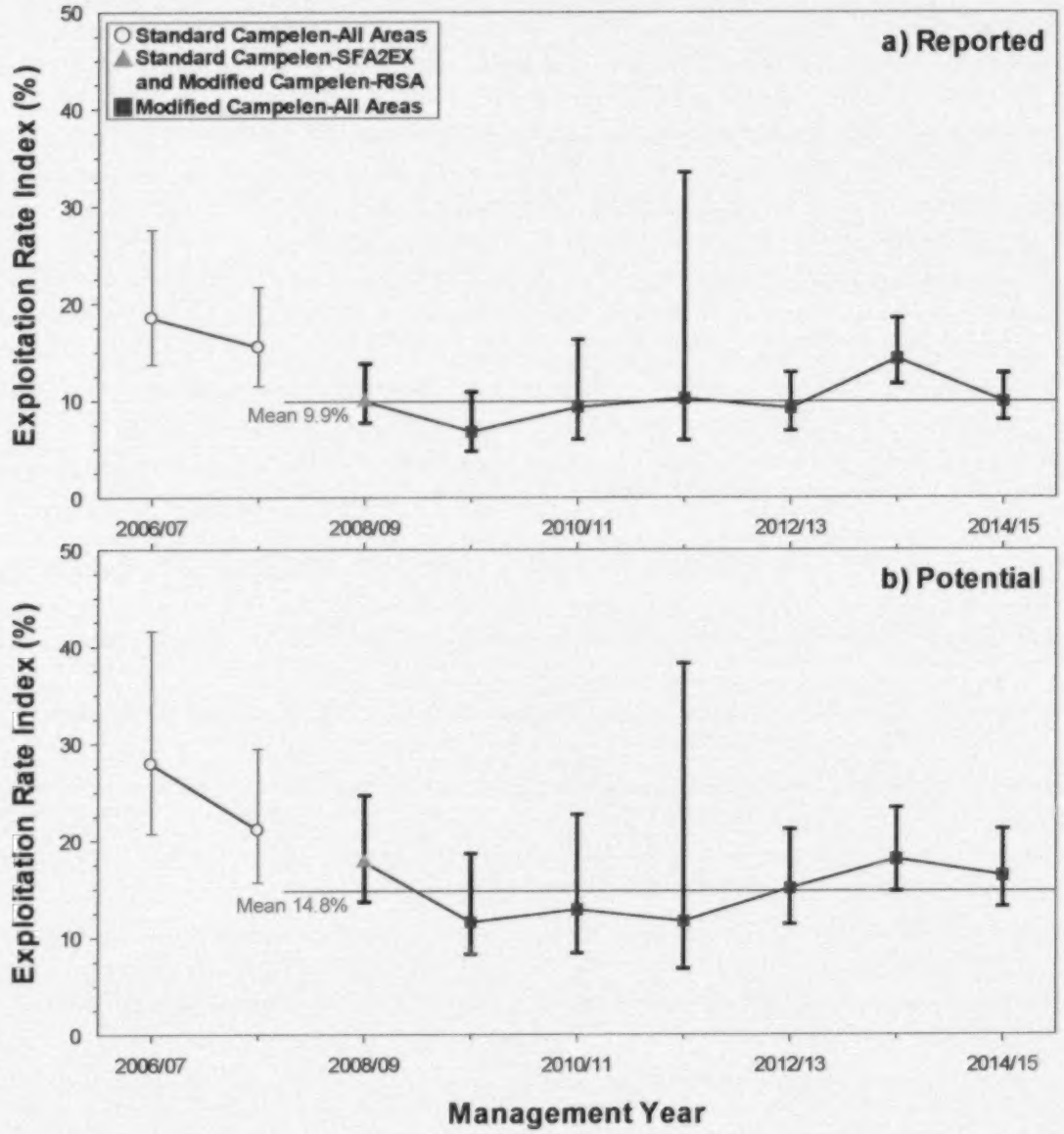

Figure 29. The Eastern Assessment Zone Pandalus borealis *exploitation rate indices for a) the observed rate based on the catch taken and b) the potential rate if the TAC assigned to the zone was taken. The first two years of survey data (2006–2007) are not considered to be comparable with the rest of series because of poor trawl performance around Resolution Island. Error bars are 95% confidence ranges.*

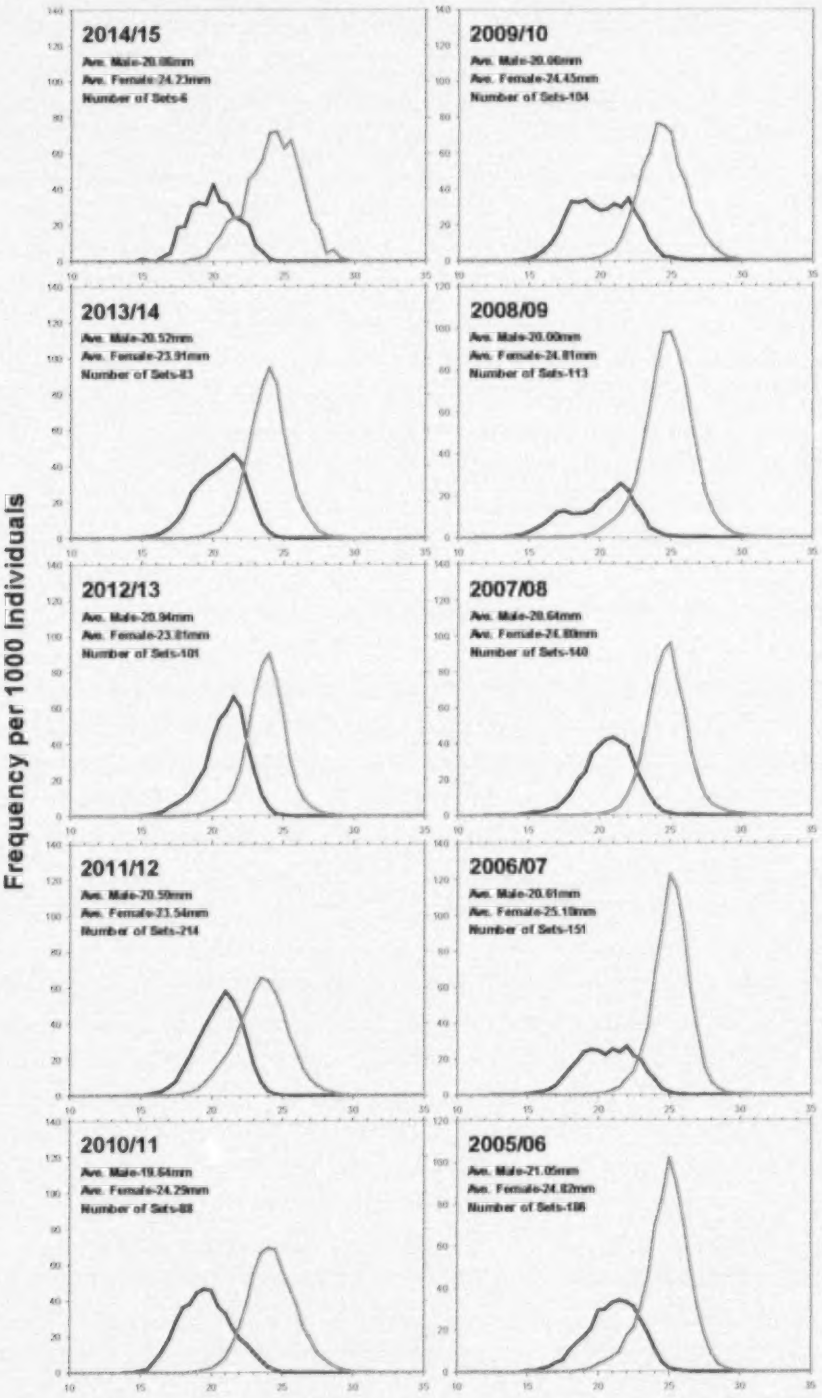

Figure 30. Length frequency of the commercial catch of male (blue) and female (red) Pandalus borealis *in the Eastern Assessment Zone over the past decade, management years 2005/06 through 2014/15.*

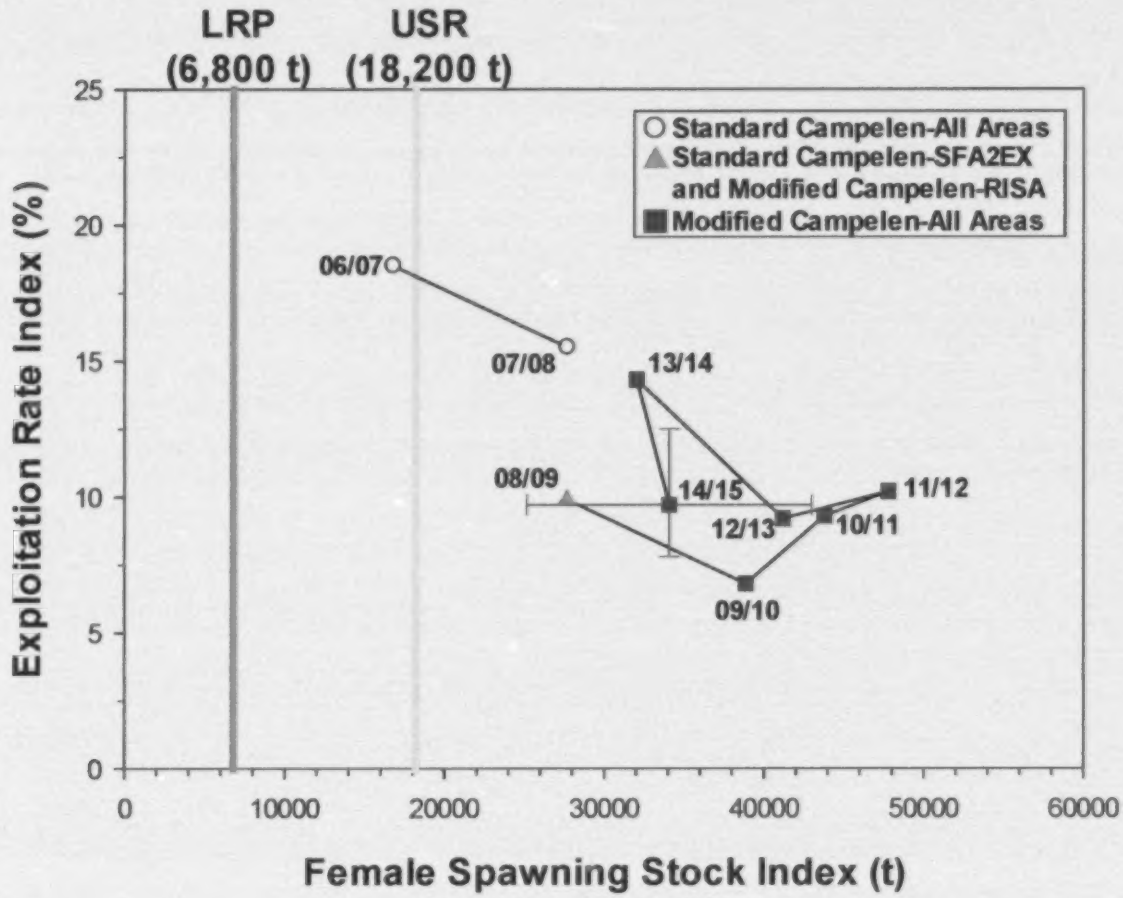

Figure 31. The Eastern Assessment Zone trajectory of Pandalus borealis *female spawning stock biomass and exploitation rate indices in relation to its reference points. USR=Upper stock reference and LRP=limit reference point are 80% and 30% respectively of the geometric mean of the SSB index (2006–2008 in SFA 2). Error bars are 95% confidence ranges.*

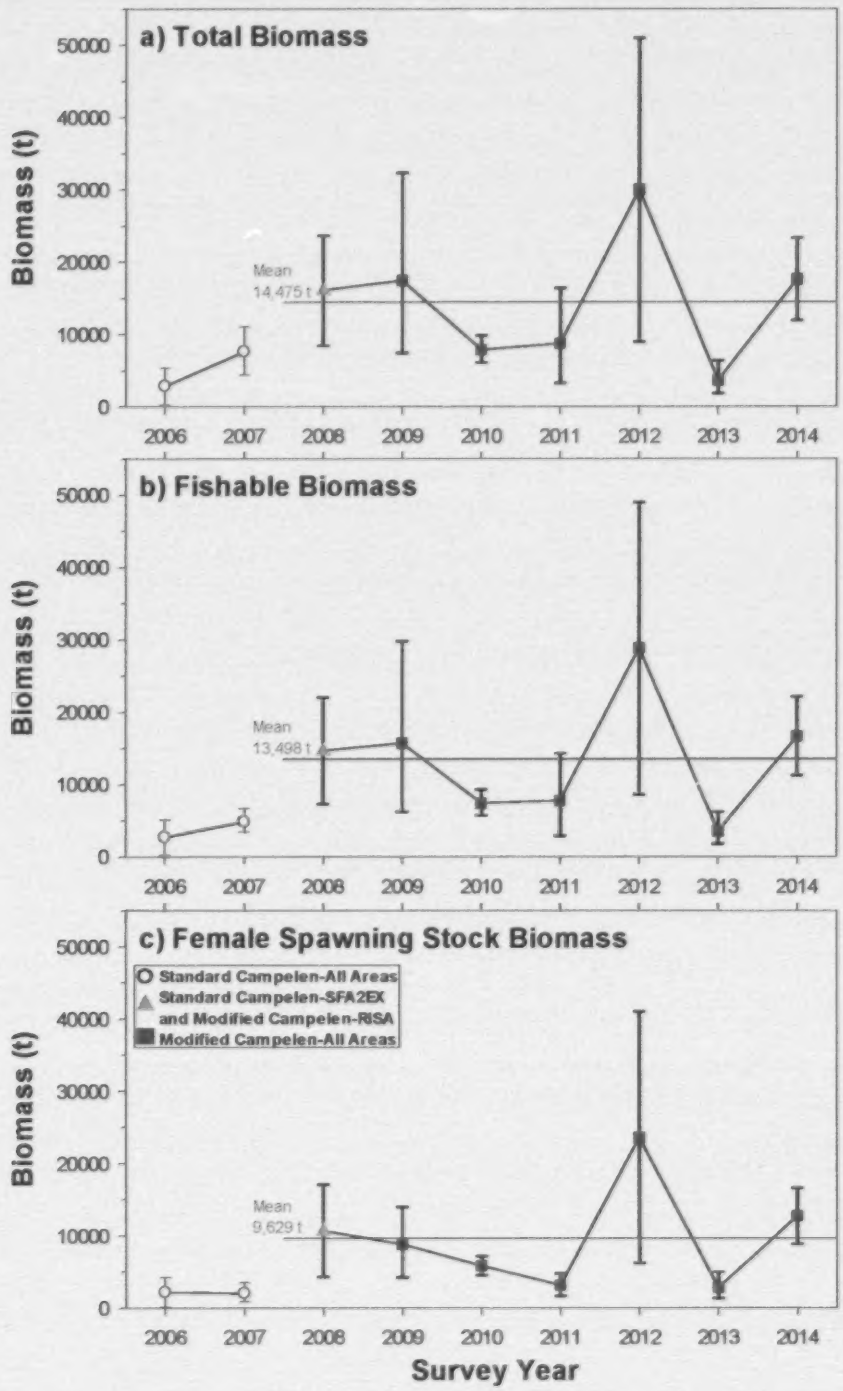

Figure 32. The Eastern Assessment Zone Pandalus montagui *total, fishable and female spawning stock biomass indices for the survey years 2006–2014. Error bars are 95% confidence ranges.*

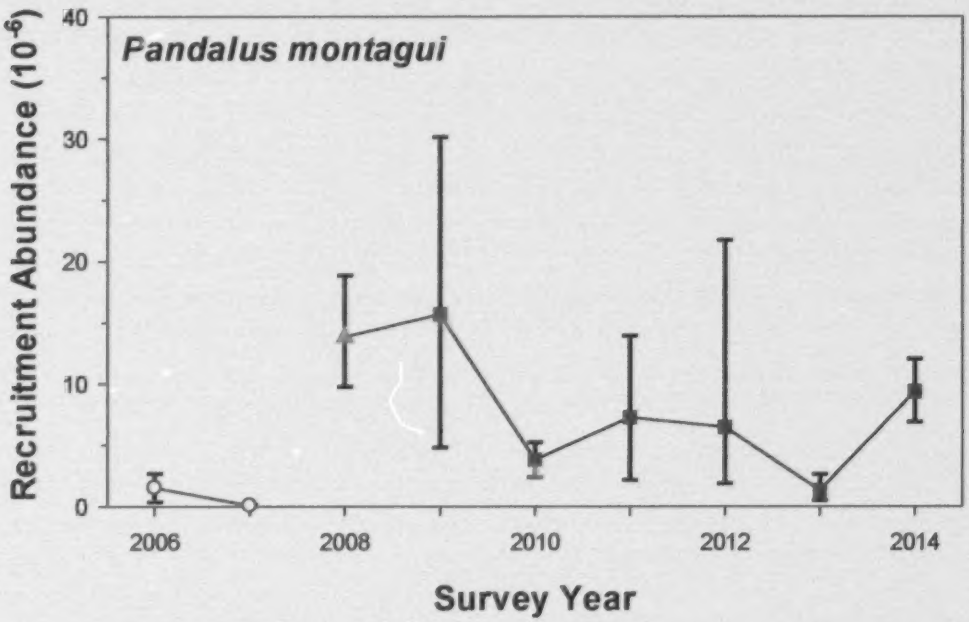

Figure 33. Recruitment index based on the Campelen cod end collection of Pandalus montagui *11.5-17.0 mm carapace length in the Eastern Assessment Zone for the survey years 2006-2014.*

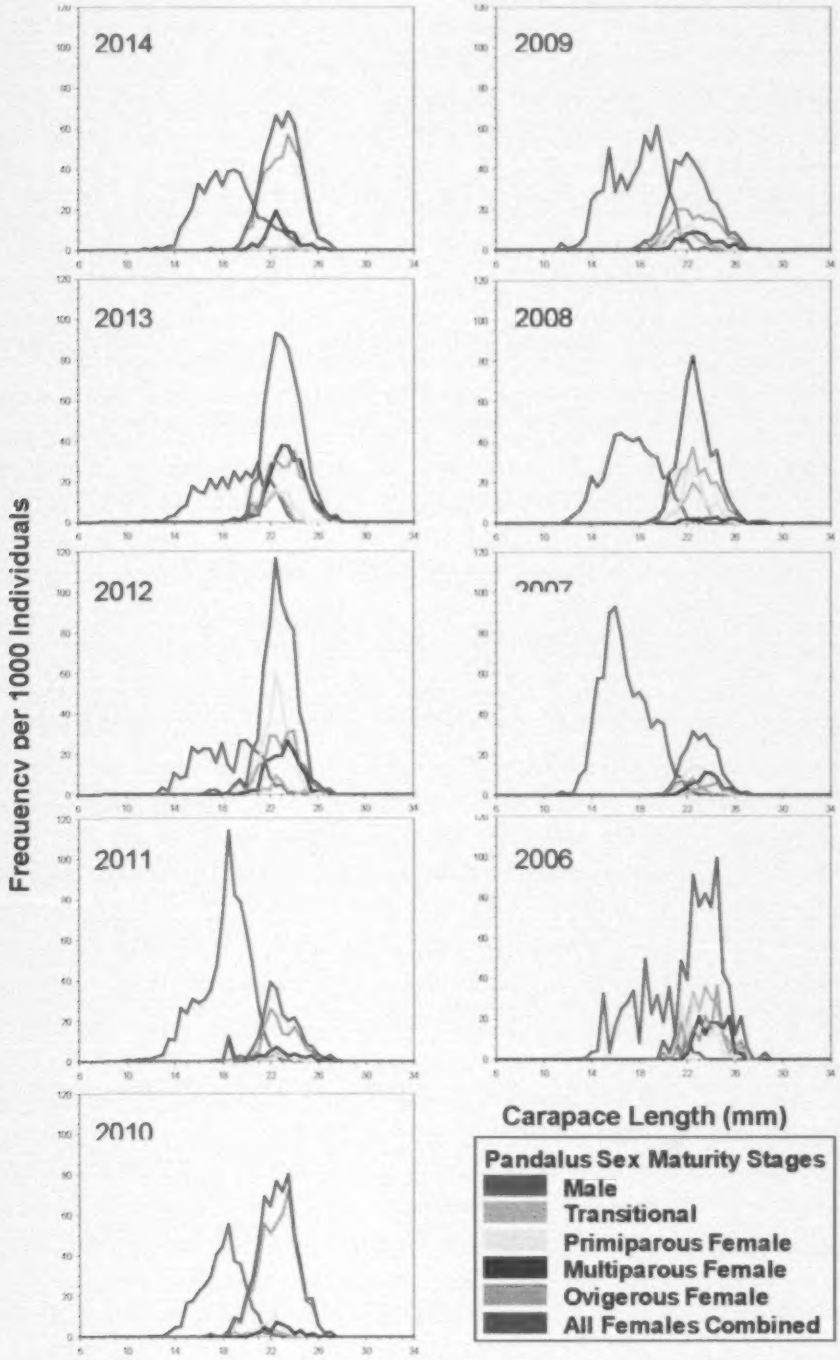

Figure 34. Length frequency curves for all sex maturities of Pandalus montagui *collected in the Campelen cod end in the Eastern Assessment Zone over the survey years 2006-2014.*

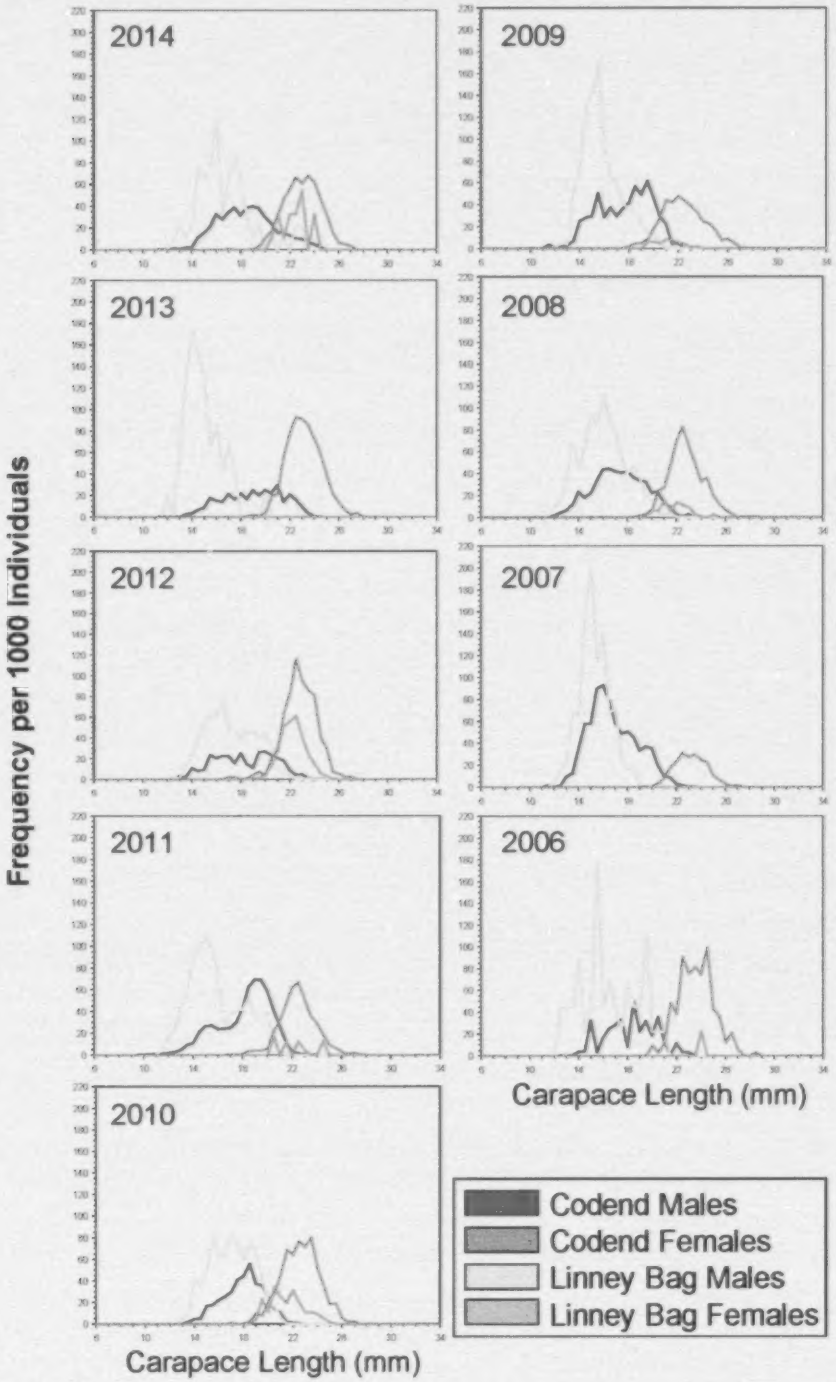

Figure 35. Overall length frequency distributions of male and female Pandalus montagui *in the Eastern Assessment Zone as captured in the cod end (CE) and Linney Bag (LB).*

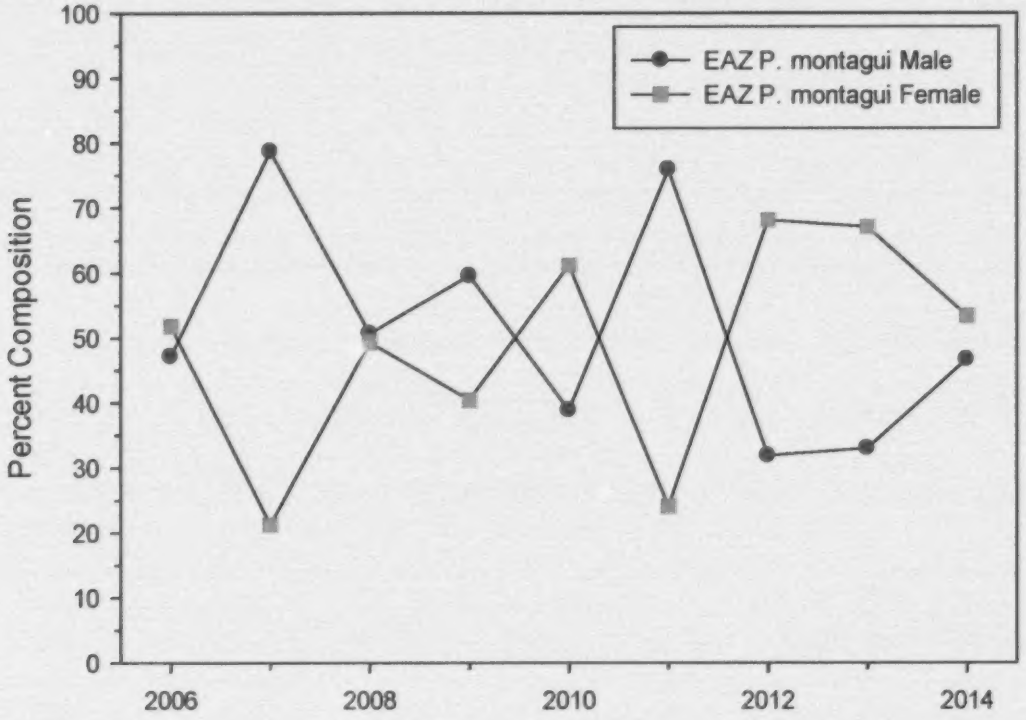

Figure 36. Percent sex composition of Pandalus montagui *in the Eastern Assessment Zone for 2006-2014.*

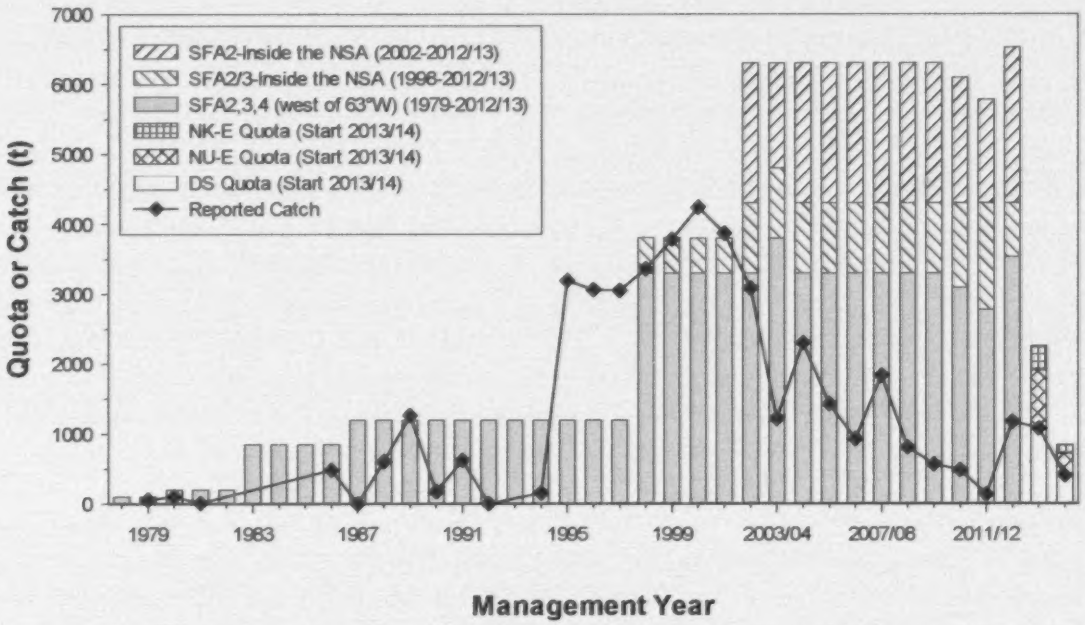

Figure 37. Eastern Assessment Zone Pandalus montagui *TAC and catch reported in the Canadian Atlantic Quota Report (CAQR). The 2014/15 data are from CAQR as of 22 January 2015.*

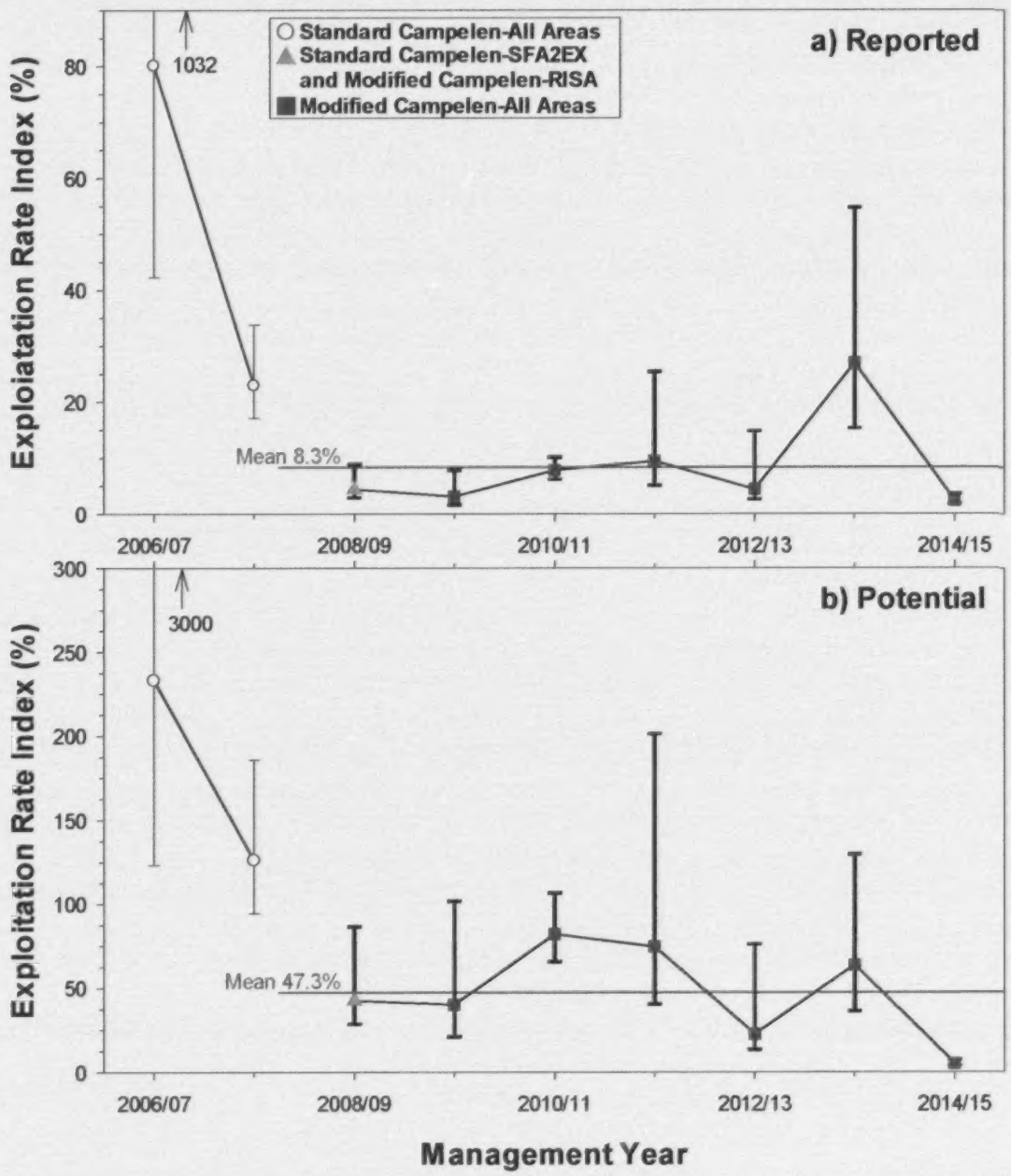

Figure 38. The Eastern Assessment Zone Pandalus montagui *exploitation rate indices for a) the reported rate, based on the catch taken and b) the potential rate if the TAC was taken. Error bars are 95% confidence ranges. Upper confidence limit for 2006/07 is shown numerically.*

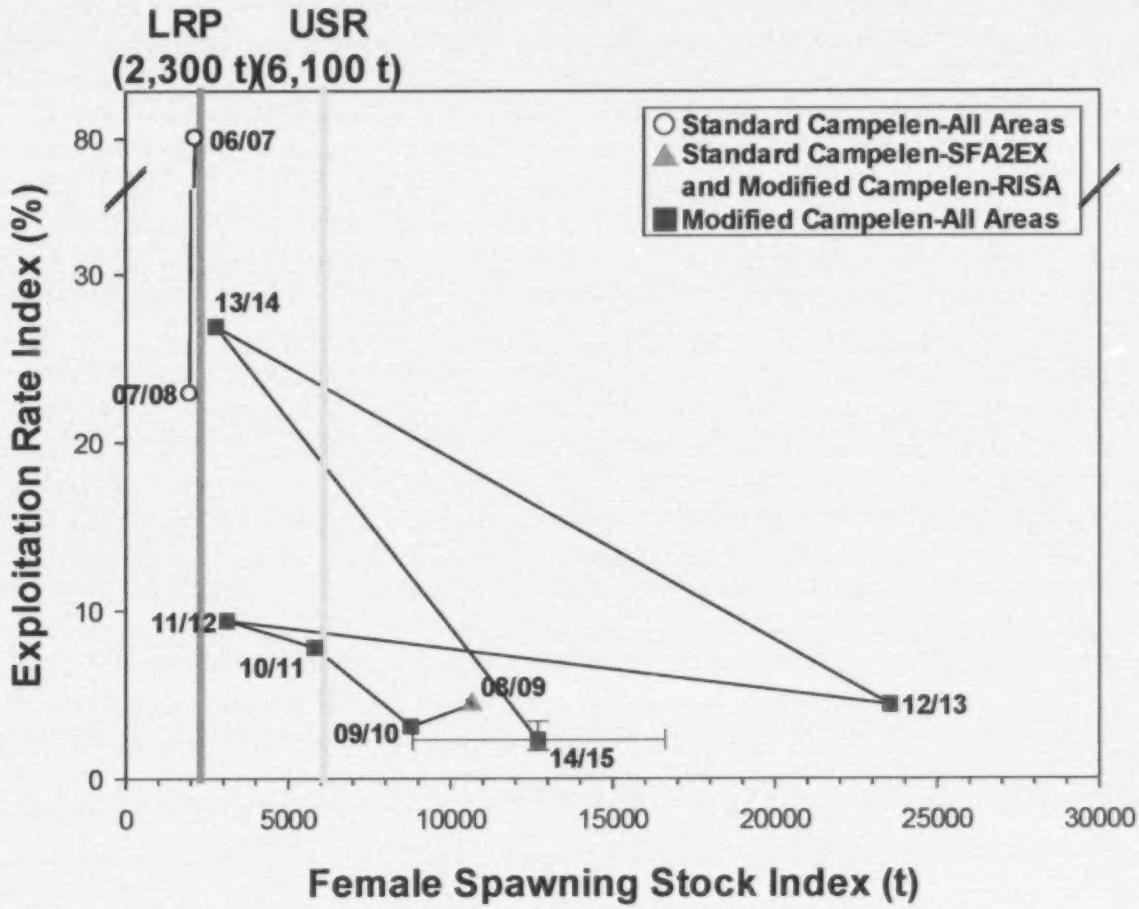

Figure 39. The Eastern Assessment Zone trajectory of Pandalus montagui *female spawning stock biomass and exploitation rate indices in relation to its reference points. USR=Upper stock reference and LRP=limit reference point are 80% and 30% respectively of the geometric mean of the SSB index (2006-2008 in SFA 2). Error bars are 95% confidence ranges.*

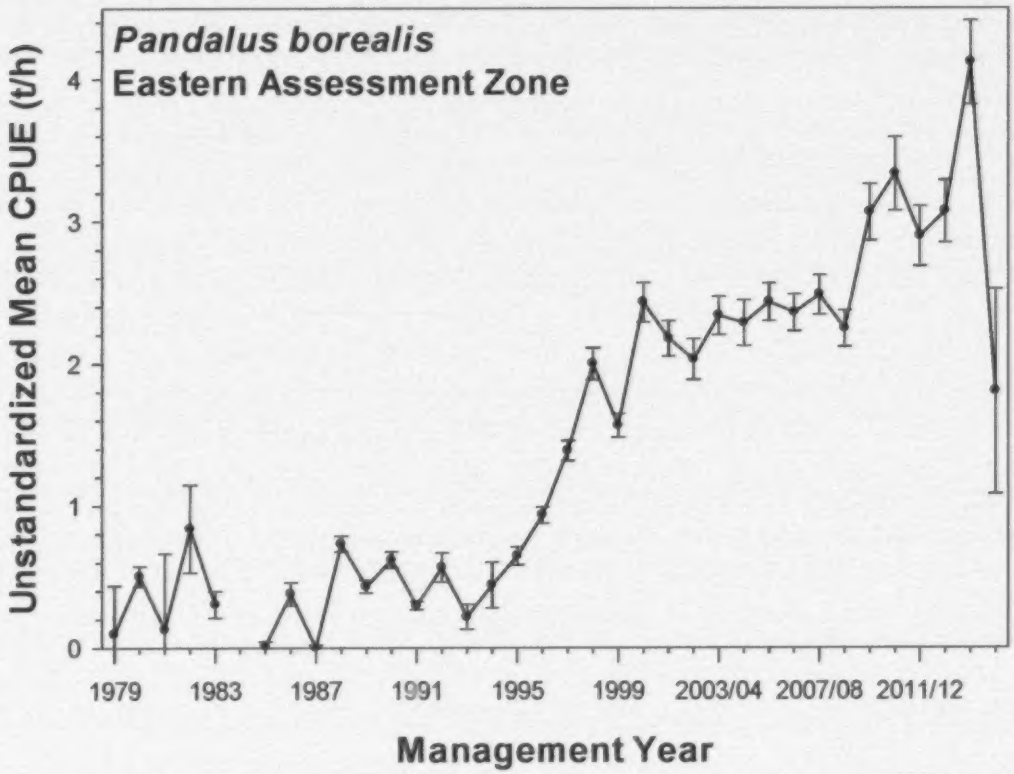

Figure 40. Unstandardized CPUE index for directed Pandalus borealis *fishing in the Eastern Assessment Zone. Observer records for 2014/15 season are incomplete.*

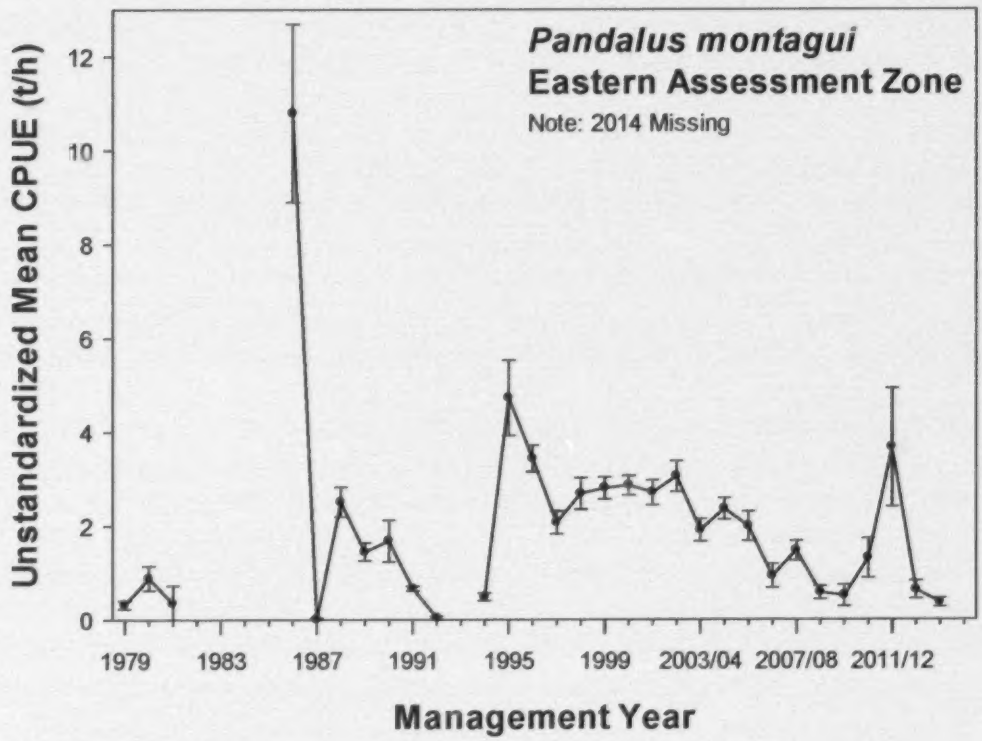

Figure 41. Unstandardized CPUE index for directed Pandalus montagui *fishing in the Eastern Assessment Zone. Note there were no* P. montagui *directed observer records available for the 2014/15 season.*

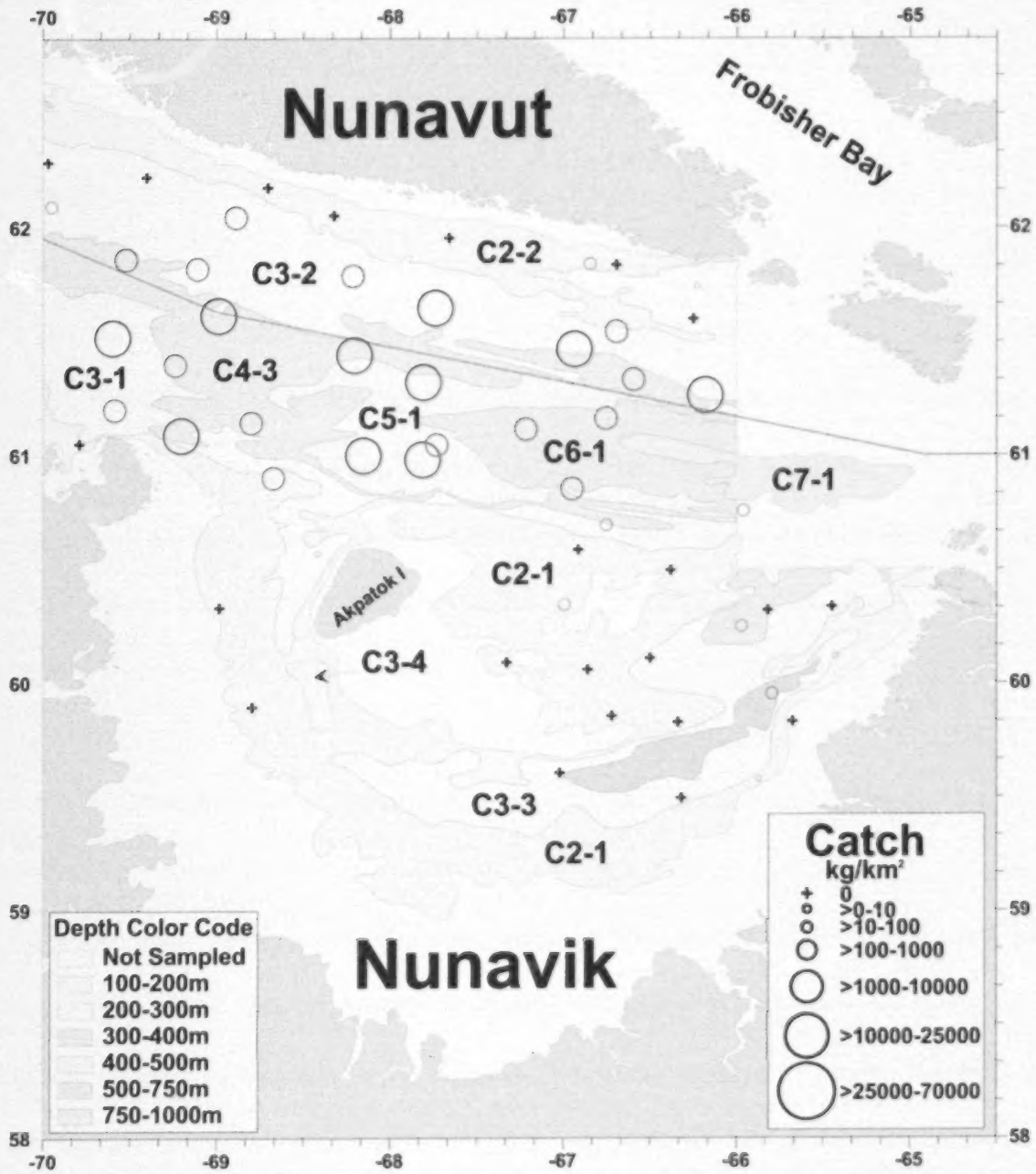

Figure 42. Standardized Pandalus borealis *catch from the 2014 Western Assessment Zone survey overlying the depth contours and strata of the survey area.*

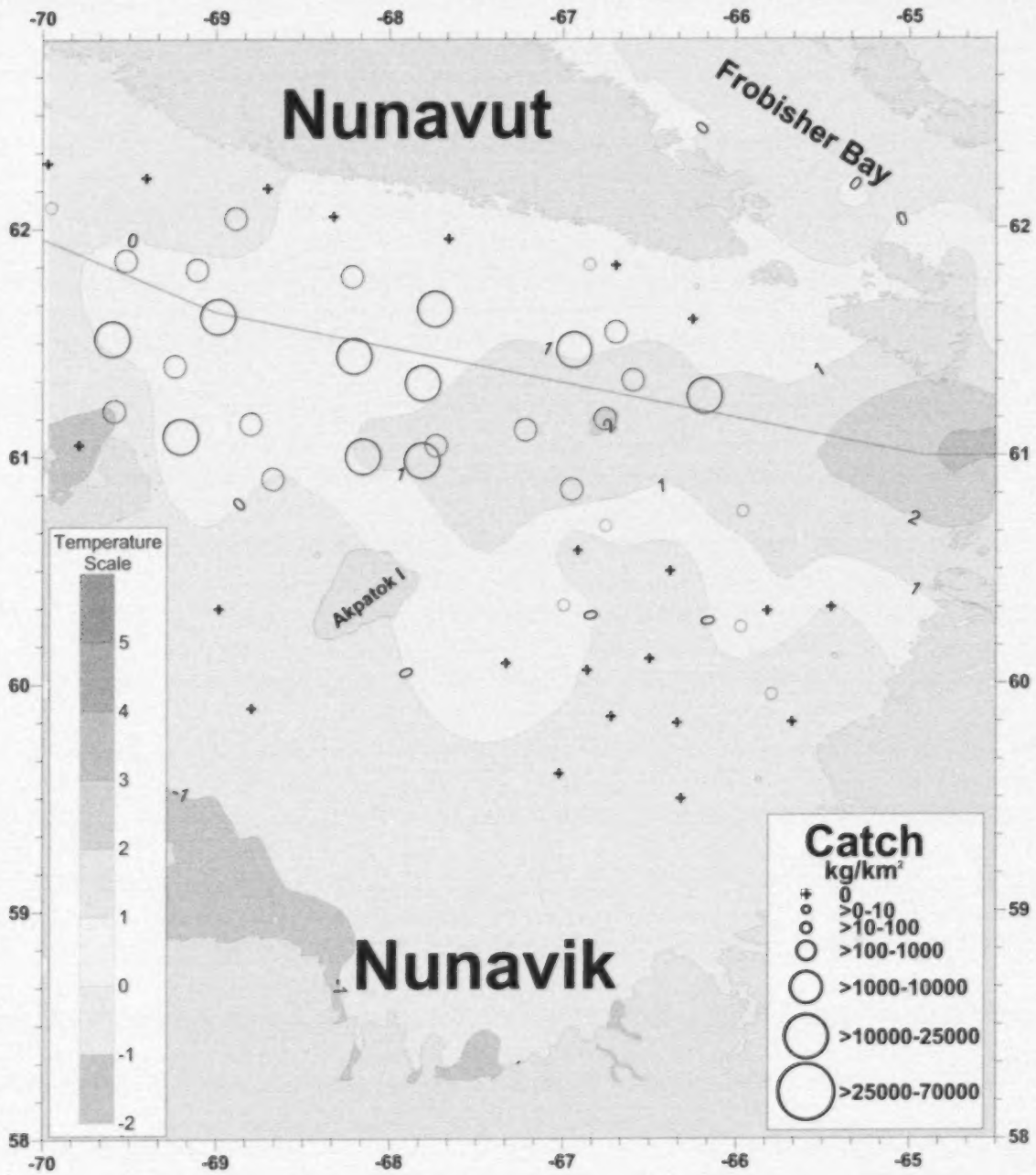

Figure 43. 2014 standardized Pandalus borealis *catch from the Western Assessment Zone overlying mean bottom temperature contours observed in the survey area.*

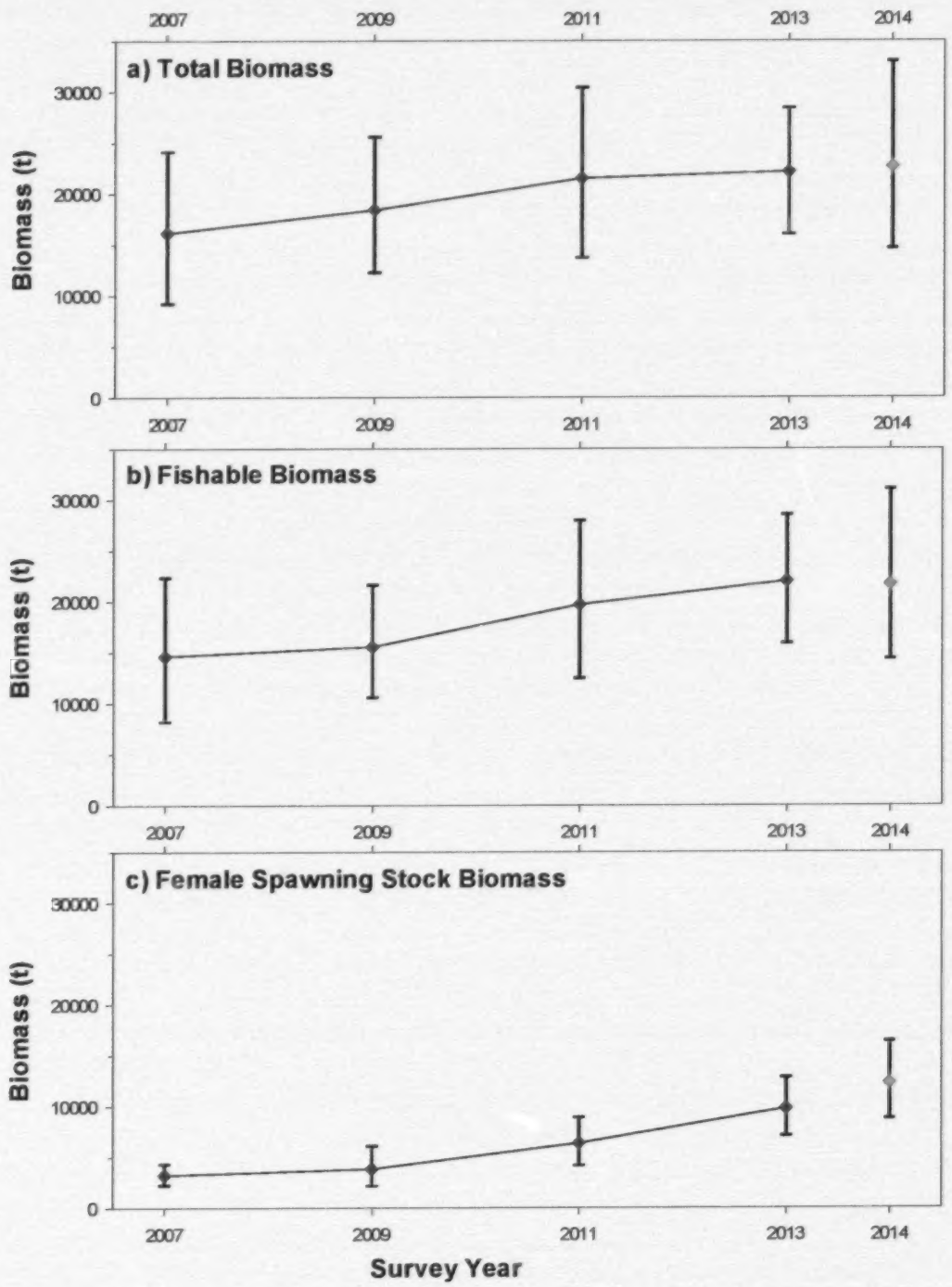

Figure 44. Total, fishable and female spawning stock biomass indices of Pandalus borealis *in the Western Assessment Zone for the years 2007, 2009, 2011 and 2013 survey by DFO and 2014 surveyed by NSRF-DFO.*

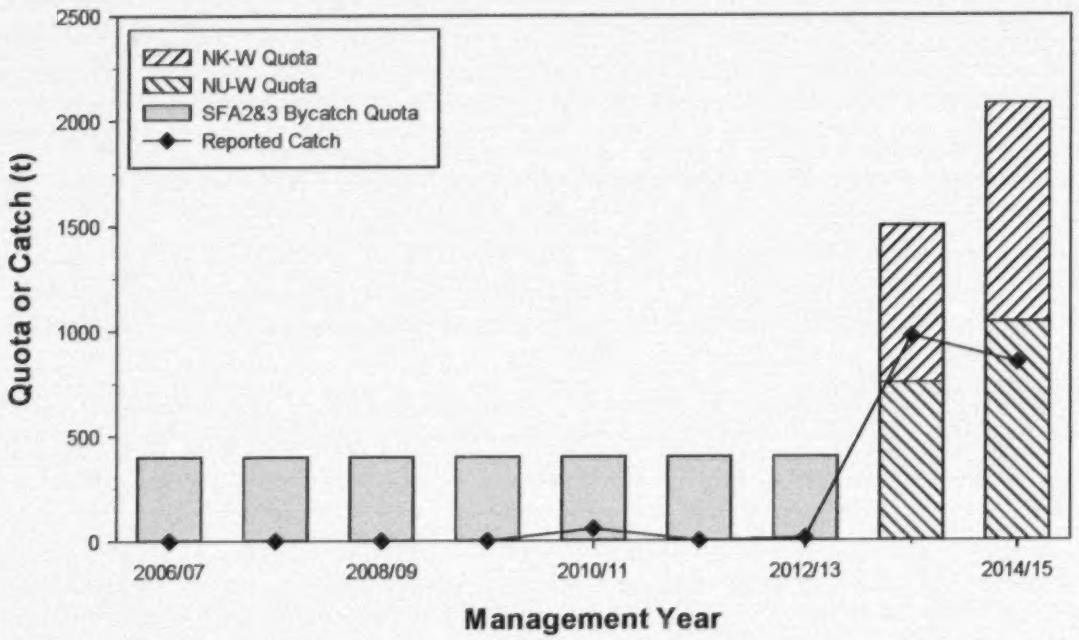

Figure 45. The Western Assessment Zone Pandalus borealis *TAC and catch recorded in the Canadian Atlantic Quota Report (CAQR) for 2014/15 and observer records prior to 2013/14. Catch records from CAQR as of 22 January 2015.*

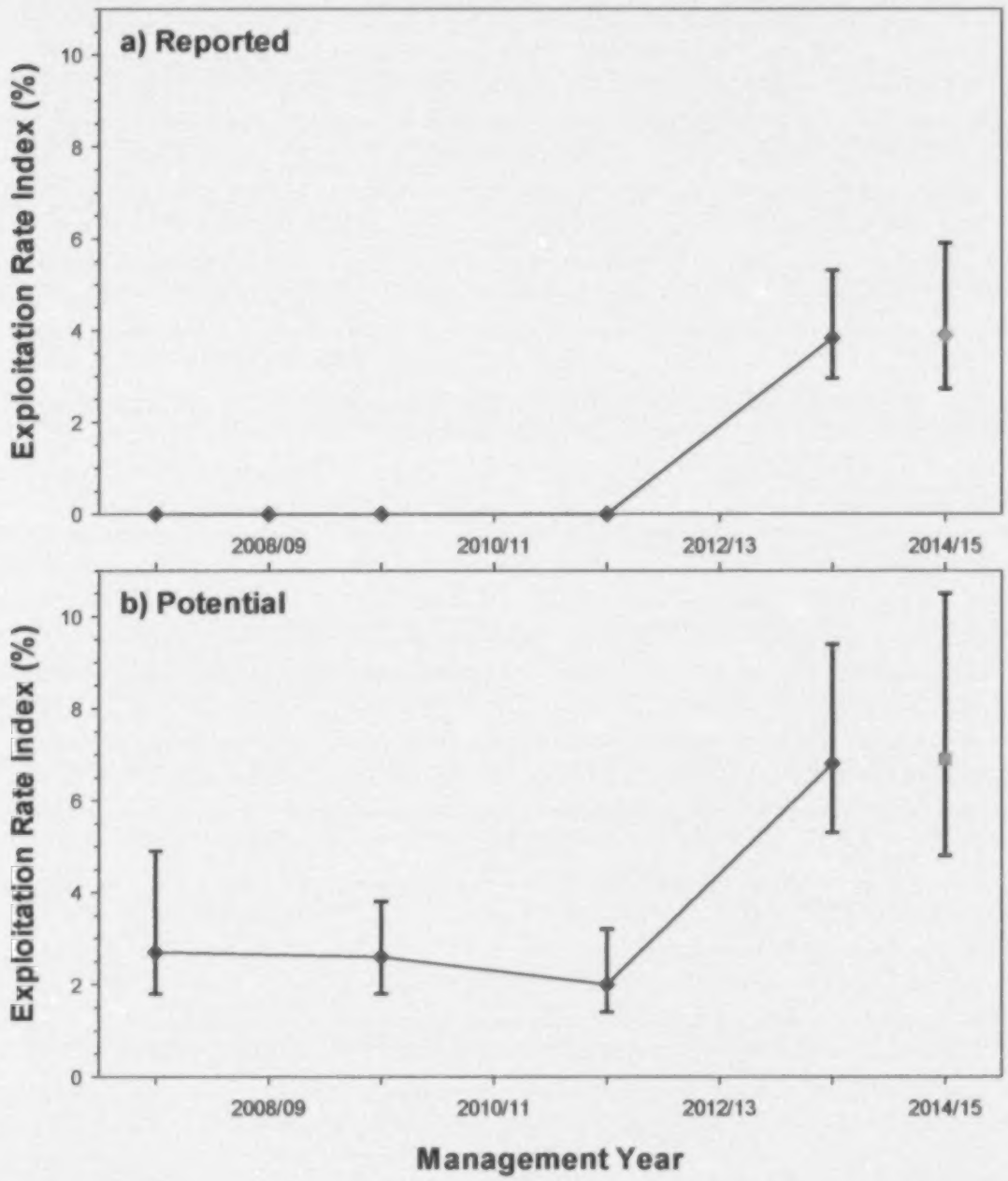

Figure 46. Pandalus borealis *Western Assessment Zone exploitation rate indices for the a) reported rate, based on the Canadian Atlantic Quota Report catch and the b) potential rate if the entire TAC assigned to the zone was taken.*

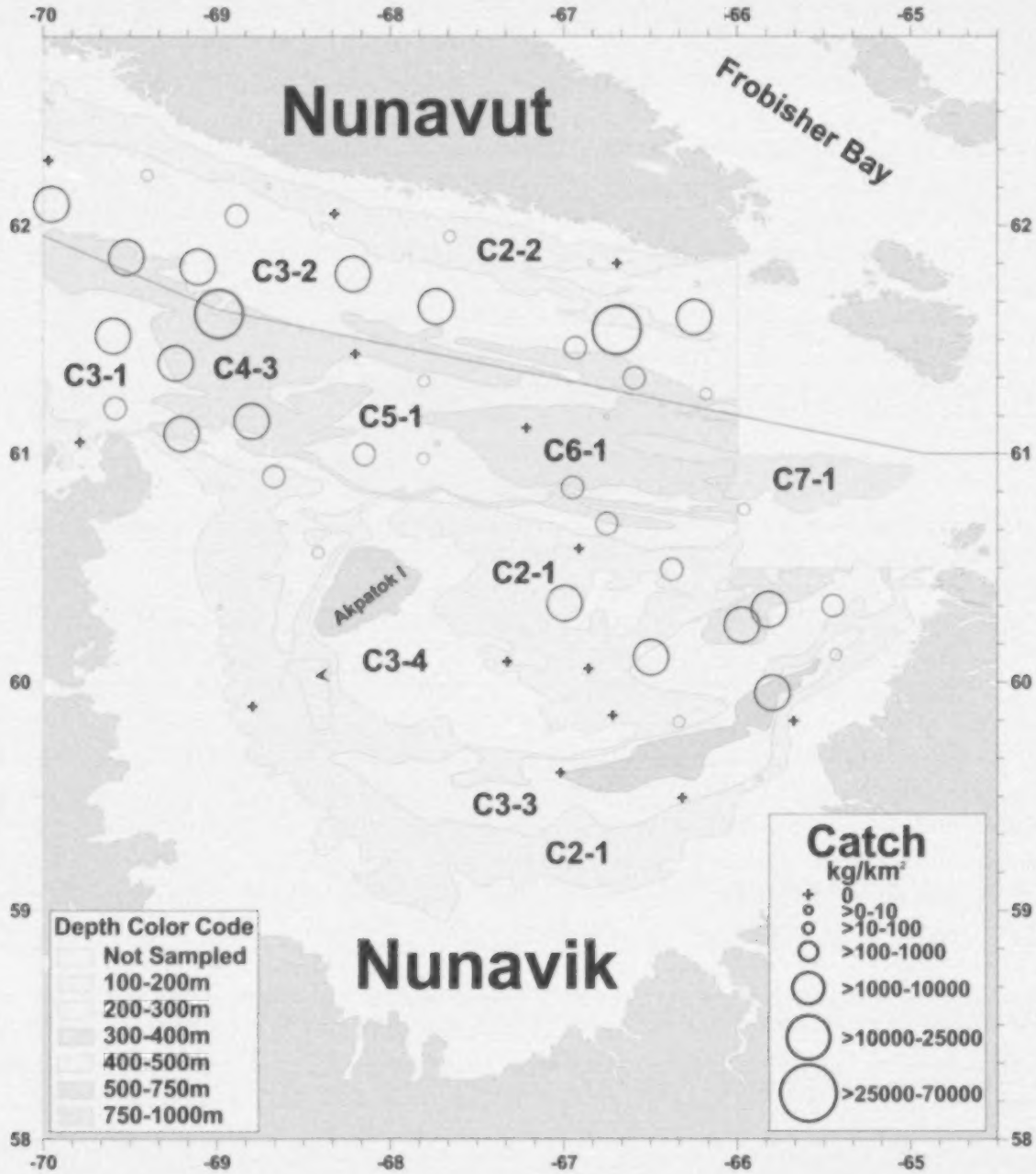

Figure 47. Standardized Pandalus montagui *catch from the 2014 Western Assessment Zone survey area overlying the depth contours and strata of the survey area.*

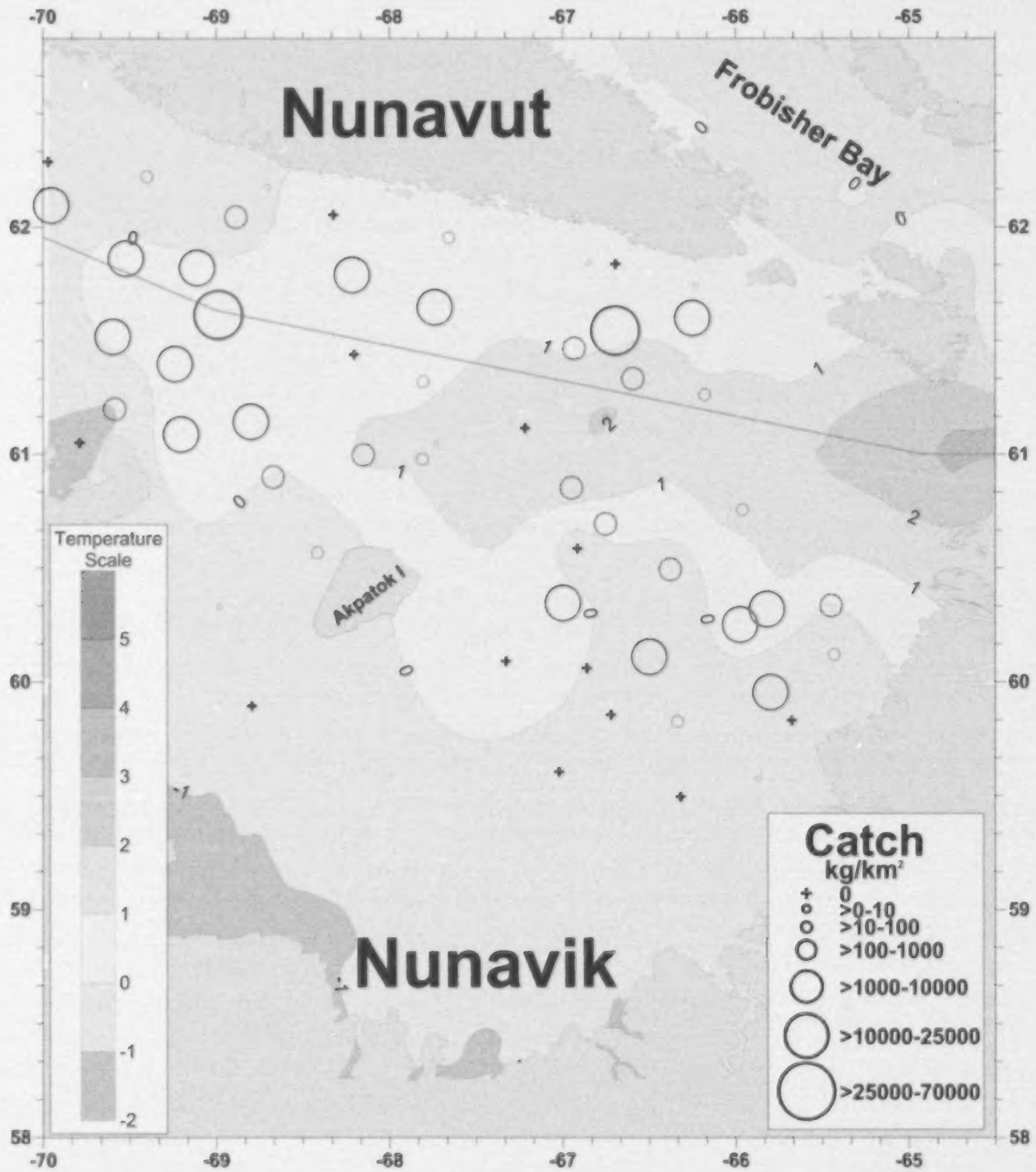

Figure 48. 2014 standardized Pandalus montagui *catch from the Western Assessment Zone overlying mean bottom temperature contours observed in the survey area.*

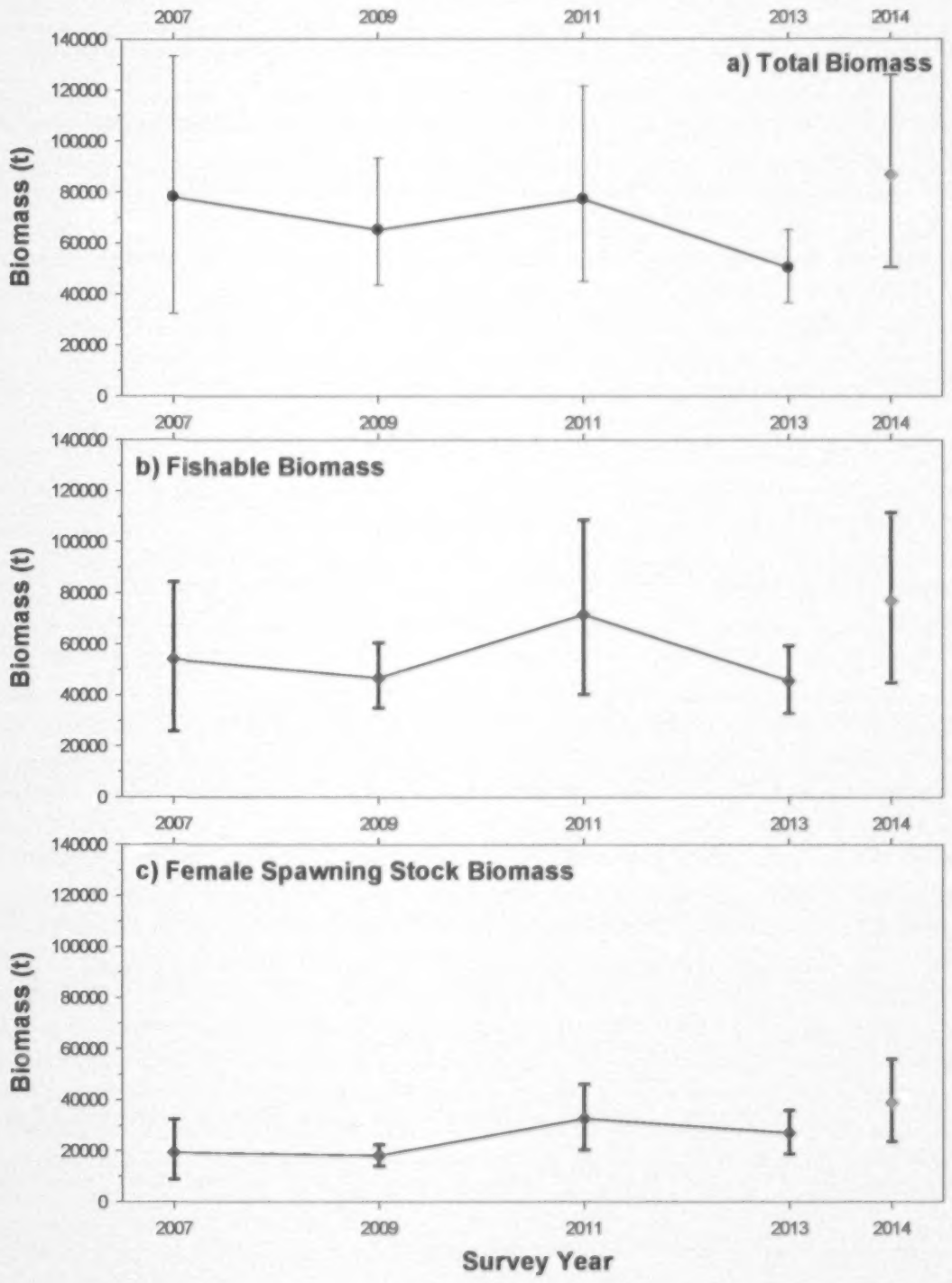

Figure 49. Western Assessment Zone Pandalus montagui, *a) total, b) fishable biomass and c) female spawning stock biomass indices. Included are four years of DFO/Cosmos surveys (blue diamonds), and the 2014 NSRF-DFO/Campelen survey (red diamond) which represents the start of a new time series. Error bars are 95% confidence ranges.*

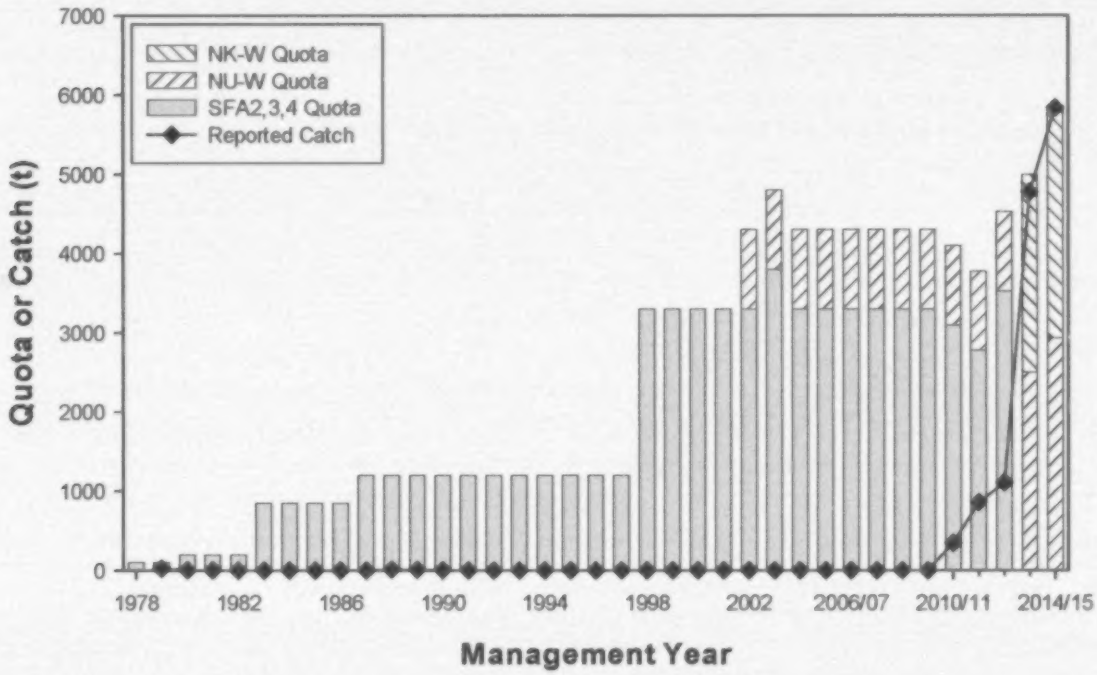

Figure 50. The Western Assessment Zone Pandalus montagui *TAC and catch recorded in the Canadian Atlantic Quota Report (CAQR). Catch based on CAQR as of 22 January 2015.*

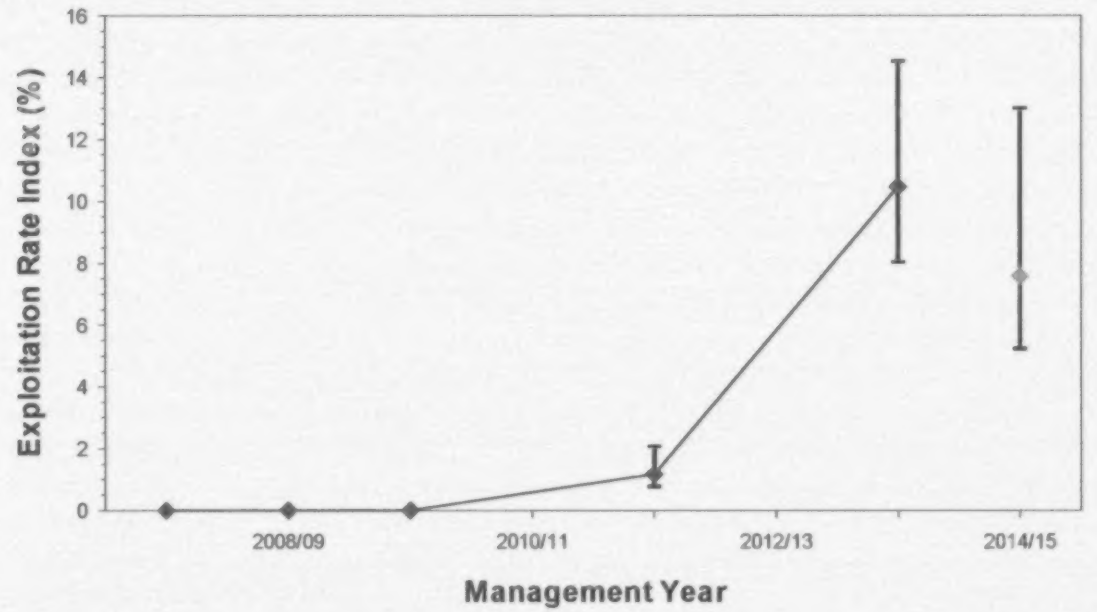

Figure 51. The reported Western Assessment Zone Pandalus montagui *exploitation rate index. The DFO/Cosmos survey (blue diamonds) is not directly comparable with the 2014 survey (red diamond) conducted by the NSRF-DFO/Campelen. 2014 represents the start of a new time series. Error bars represent 95% confidence range.*

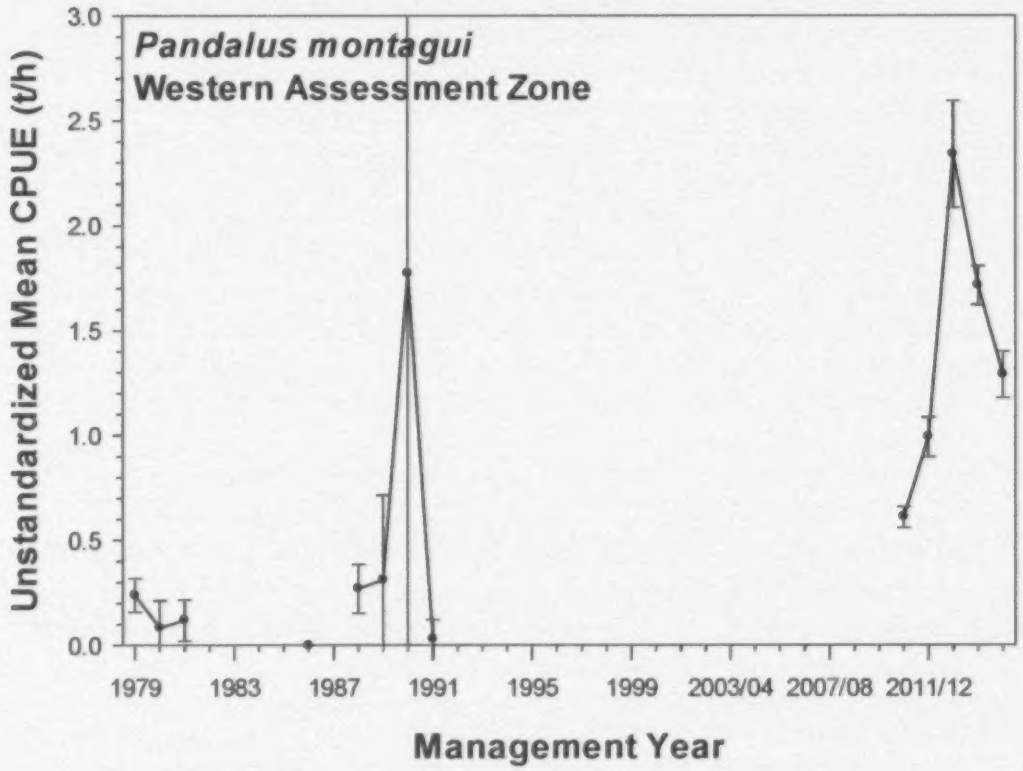

Figure 52. Unstandardized CPUE index for directed Pandalus montagui *fishing in the Western Assessment Zone. Observer records for 2014/15 season may be incomplete.*